THREE ESSAYS ON HOUSEHOLDS' LOCATION DECISIONS: ANALYSIS OF THE PROCESSES OF GENTRIFICATION AND RURAL-URBAN MIGRATION

BY

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DISSERTATION

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Abstract

Using econometric, theoretical and modeling approaches, this dissertation studies how the processes of gentrification and interregional migration affect the location decisions of individuals. The first paper analyzes the effect of gentrification on the housing price premium distribution using data from Chicago. Assuming a monotonic relationship between housing prices and income, the results suggest that gentrification causes displacement of the low-income population because the appreciation of houses in the lower tail of the distribution is greater in properties located in gentrified neighborhoods. The estimations correct for endogeneity of the gentrification definition, and for the spatial correlation of housing prices.

The second paper develops a general equilibrium model of workers' interregional allocation. The model considers an economy with two sectors called manufacturing and violence, and mobile labor and capital. Workers choose their location by observing the wage differentials and two distortions in the economy: the existence of unemployment in the cities and a distortion in the violence sector related to the "guilt and fear" faced by individuals working there. An increase in the manufacturing wage increases the unemployed labor in the cities, but the effect is lower when the initial unemployment is high. On the other hand, an increase in the manufacturing wage could either increase or decrease the violence labor, and these changes are less positive (or more negative) with high initial levels of violence.

Finally, the third paper uses a CGE-microsimulation model to analyze the effects of an ex ante legalization of drugs on the Colombian economy. Changes in wages and migration are estimated using a labor participation model, and households demand and welfare measures are calculated using the Almost Ideal Demand System. The impacts of legalizing drugs are analyzed under different scenarios with different assumptions regarding the changes in drug price, government investment and the termination of the armed conflict. If the legalization of drugs ends the armed conflict, economic welfare is only improved if the government reinvests the military expenditures into other productive sectors. If the armed conflict does not end with legalization, the legalization of drugs could improve economic welfare in rural and urban areas. These welfare effects are not monotonic with income; the lowest income deciles benefit more than the highest deciles, with rural areas benefiting more than urban areas.

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Chapter 1

Introduction

Most of the early migration studies have focused on migration between different countries, but studies about households' allocation within cities, or interregional migration between rural and urban areas have been studied as an important issue of development and urbanization only since the 1950s. Households' allocation within cities affect the dynamics of the urban center, influencing issues such as racial and income segregation, segmented housing markets, and neighborhoods effects. On the other hand, rural-urban migration is a phenomenon that affects not only economic growth, but also the social well-being of individuals and the evolution of cities as urban centers of development. Using econometric, theoretical and modeling approaches, this dissertation studies how the processes of gentrification and interregional migration affect the location decisions of individuals.

Since the 1970s, the literature began analyzing the concept of "urban poverty" as a consequence of the rural-urban migration and within-city segregation (Berner, 2001). Migration is not only associated with modernization and economic growth, but also with urban disamenities generated by rapid population growth and the inability of the modern sector to absorb the new labor supply. Heterogeneity within the city produces segregation among communities, and neighborhood sorting exacerbates the urban conditions for new immigrants and minorities. Ethnic enclaves have been often created in U.S. cities as a consequence of the urbanization processes, and most of the urban poverty observed in the country occurs in neighborhoods where the majority of the population belongs to a minority or to an immigrant group (Jargowsky, 1997). In contrast, in developing countries, new immigrants are employed mainly in the informal sector and are segregated to areas in the cities where the land market is not regulated and where there is limited access to public services (Berner, 2001). The gap between the income distribution of existing residents and that of new immigrants or minorities has increased, and welfare differentials in the urban areas have been affected by the increasing urbanization of cities.

Although the theoretical models of Tiebout (1956) and Schelling (1969) explain how the complete sorting of households is achieved through household allocation choices, recent urbanization processes such as the process of gentrification in different U.S. cities have shown that perfect segregation is broken when low-income

city neighborhoods face housing renovations followed by an influx of mid- and high-income populations. The Tiebout model explains how the level of expenditures for local public goods reflects the preferences of a population. For example, an individual's decision to move from one community to another depends on his preferences for the public goods that are locally provided. On the other hand, Schelling studies segregation from the perspective of the discriminatory choices of individuals. Making a two-fold distinction, he finds that ethnically mixed areas do not constitute a stable equilibrium because people often tend to create clusters with other people who are similar, often producing a complete segregation between two groups. The decision of high-income households to migrate to city neighborhoods due to amenities attractiveness, housing renovation, or lower transportation costs, affects the demographic dynamics in the city. While some studies suggest that segregation increases because of the displacement of low-income population from gentrified neighborhoods, some others claim that gentrification is an effective policy to reduce segregation and create mixed-communities.

In chapter 2, the effect of gentrification in the lower tail of the housing price premium distribution using individual housing transactions in the city of Chicago is estimated to make inferences about population displacement from gentrified neighborhoods. The housing premium is defined as the appreciation of housing prices from 2000-2005, and the gentrification variable is defined as a combination of two phenomena: housing renovation and influx of mid- and upper-income households to low-income neighborhoods. Using quantile regressions with three different specifications, the results correct for endogeneity of the gentrification definition and for the spatial correlation of housing prices. The results are robust in different specifications: housing prices in gentrified neighborhoods appreciate more than in non-gentrified neighborhoods in every percentile of the distribution, including prices located in the lower tail. Assuming a monotonic relationship between housing prices and income, these results suggest that gentrification appreciates the prices of low-value dwellings generating displacement of the low-income population. However, the appreciation is lower in the lower tail than in the upper tail of the price premium distribution, suggesting that the influx of high-income populations to gentrified neighborhoods is stronger than the displacement of low-income households.

Using a theoretical model, chapter 3 analyzes workers' allocation between rural and urban areas when the migration decision depends also on noneconomic factors. Since the decade of the 1950s, noneconomic factors have played an important role on understanding migration. Wolpert (1965) develops the idea of *place utility* to understand migration. Different locations offer different amenities and households observe this "bundle" of characteristics in each location and choose the one that maximize their utility. Migration occurs when the expected utility in a different place is greater than the utility received in the current place

(Brown and Moore, 1970). Some of the migration studies that consider noneconomic factors are Cole and Sanders (1985), Yap (1997), Gelan (2002), Gonzalez-Rodriguez (2005), Stark and Taylor (1991), and Stiglitz (1974), among others.

Following Harris and Todaro (1970), chapter 3 uses a general equilibrium model to explore the impact of changes in the manufacturing wage on employment and prices. The model considers an economy with mobile labor and capital and two sectors called manufacturing and violence (including for example, illegal drug business). The labor migration between manufacturing and violence activities depends not only on the wage differentials, but also on non-economic factors such as the unemployment rate in cities and a distortion in the violence sector related to the "guilt and fear" faced by individuals working there. The effect a policy to increase the minimum manufacturing wage depends on the initial conditions of the economy. An increase in the manufacturing wage increases the amount of unemployed labor in the cities, but the effect is lower when the initial unemployment is high. On the other hand, the disutility faced by violence workers is greater with high levels of initial violence. An increase in the manufacturing wage could either increase or decrease the violence sector labor, and these changes are less positive (or more negative) with high initial levels of violence. The paper concludes with a policy implication analysis of the tradeoff between decreasing violence and decreasing unemployment, and compares the results of the model with the illegal drug market in Colombia.

Chapter 4 analyzes households' location choices between rural and urban areas using data from Colombia. Colombia is an interesting case study for analyzing migration, because the rural areas have an armed conflict that is linked with the production and trafficking of illegal drugs. Then, migration to the cities is triggered not only by wage differentials, but also by socio-political factors related to the insecurity that households face in the rural areas. Studies that analyze the migration decision of the displaced population include Lozano-Gracia et al. (2010), Schaeffer (2010), Ibanez and Velez (2008) and Villa and Rodriguez (2010). The last report of the Global Commission on Drug Policy of June 2011 concludes that the war on drugs imposed 50 years ago by President Nixon and by the U.N., has failed. The problems associated with the drug trafficking include violence, intimidation, drug dependency, and domestic and international displacement. In this chapter, I analyze the effects on the Colombian economy of legalizing drugs.

Using a computable general equilibrium (CGE) microsimulation model, the effects of an ex ante legalization of drugs on the Colombian economy are analyzed. The model consists of eleven productive sectors (including illegal activities), three different labor force categories with unemployment, and twenty households divided by income and location (rural and urban). Changes in wages and migration are estimated using a labor participation model. An Almost Ideal Demand System estimates the households' demand of the CGE

model, and it is also used to estimate the impacts on economic welfare, once the shock of legalization is simulated. The impacts of legalizing drugs are analyzed under six different scenarios with different assumptions regarding the changes in drug price, government investment and the termination of the armed conflict. The results suggest that household economic welfare is very sensitive to reinvestments the government makes in the economy. If the legalization of drugs ends the armed conflict, economic welfare is only improved if the government reinvests the military expenditures into other productive sectors such as health, education and transportation. If the armed conflict does not end with legalization and the "economy of war" continues, the legalization of drugs could improve economic welfare in rural and urban areas. These welfare effects are not monotonic with income; the lowest income deciles benefit more than the highest income deciles, with rural areas benefiting more than urban areas.

The appendix provides additional explanation for the methodology used in chapter 4 to link the CGE models with microsimulation models. Because all the agents in the economy are affected, the shock is analyzed using a CGE model. However, when the interest centers on poverty or welfare impacts at the household level, microeconometric models are needed in order to account for microeconomic behavior of households. The CGE model interacts with two microeconomic models: a labor participation model to measures migration decisions of households, and an Almost Ideal Demand System (AIDS) to estimate household demand and calculate welfare measures of different household groups. The interaction between the CGE model and the labor participation model considers feedback loops from top to bottom and behavioral responses from households at the microeconomic level. On the other hand, the interaction between the CGE and the AIDS could be described in two steps: I first use the AIDS model to estimate the budget shares, to use in the CGE model, and then I use the changes in income and prices from the CGE model in the AIDS framework to calculate the welfare measures of different household deciles.

Chapter 2

The effects of gentrification on the housing price premium distribution: Evidence from Chicago

2.1 Introduction

Many large American cities have recently undergone urban renewal processes better known as gentrification, urban revitalization or neighborhood renewal processes. Urban renewal refers to housing renovation followed by the process of resettlement of the upper middle class into low-income city neighborhoods (Clay, 1979). Although some authors suggest that low-income populations are not displaced from these neighborhoods (see Freeman, 2009; and McKinnish et al., 2010), others suggest that urban renewal increases income disparities and racial segregation in the inner cities as a result of the influx of middle- and high-income populations into gentrified neighborhoods (Walks and Maaranen, 2008; Lees, 2008). A better way to understand the effects of urban renewal processes is to analyze their effect on the housing price premium distribution, and then, make inferences about the income composition of gentrified neighborhoods, and compare it to the one of non-gentrified neighborhoods.

The socioeconomic effects of urban renewal processes have been analyzed both qualitatively and quantitatively. Joseph and Chaskin (2010) conduct surveys in gentrifying neighborhoods in Chicago to analyze the perception of the gentrified and the gentrifying population in terms of displacement, quality of life and social relations. DeVerteuil (2010) perform a similar exercise in some gentrified neighborhoods of London and Los Angeles by analyzing the displacement of social services facilities as a proxy of displacement of the population. Recent quantitative analyses that focus on the causes of gentrification, its consequences, and the study of mixed-income communities include studies by Freeman (2005), Freeman (2009), McKinnish et al. (2010), Brueckner and Rosenthal (2009), Bostic and Martin (2003), and Atkinson (2003) among others . Epple and Sieg (1999), Galster (2007), and Galster and Booza (2007) have investigated the existence and stability of mixed-income neighborhoods in central locations using theoretical models of population sorting, finding an optimal combination of economic efficiency and distributive equity, and calculating entropy indexes to define bipolar neighborhoods.

Using individual housing prices from Chicago, this paper aims to explain the effect of gentrification on

the housing price premium distribution, specifically in the lower tail of the distribution, in order to make conclusions about the displacement of the low-income population from gentrified neighborhoods. I use two different specifications of quantile regressions to control for endogeneity of the gentrification definition, and for the spatial correlation of housing prices: in the first case, I implement the quantile treatment effect (QTE) estimator developed by Abadie et al. (2002) using the proximity of the neighborhoods to an Alderman's ward office as an instrument. In the second case, I consider the spatial dependence of housing prices and correct for spatial autocorrelation using kernel weighted quantile regressions.

This work contributes to the growing body of literature related to gentrification in urban areas by explaining the effect of urban renewal in the housing price distribution and inferring for displacement of population using a quantitative approach. Although quantile regressions have been used before to calculate housing price indexes and to estimate the specific marginal effects of housing characteristics in different percentiles of the housing price distribution (McMillen, 2008; Mak et al., 2010; Zietz et al., 2008, among others), to the best of my knowledge, this paper is the first to use quantile regressions, both parametrically and non-parametrically, to estimate the effects of gentrification on the appreciation of housing prices. Additionally, I test my results by controlling for the endogeneity of the gentrification definition and the spatial correlation of housing prices.

Chicago has been an interesting case study in the gentrification literature because of the frequent and widespread relocations that have occurred in past decades, and the attempts made by the city to implement several programs to avoid segregation in neighborhoods (Lin, 2002; Nyden et al., 2006; Helms, 2003; and Betancur, 2002). The Chicago Housing Authority (CHA) and the Department of Housing and Urban Development (DHUD) have attempted to reduce the level of housing segregation in the city by creating mixed-income housing development programs such as the Gatreaux program, the HOPE VI housing redevelopment program, the Lake Park Place program, and the Plan for Transformation (for details, see Joseph and Chaskin, 2010; Wylyl and Hammel, 2000; and vonHoffman, 1996). If the effect of urban renewal processes is different on different percentiles of the housing price distribution, the gentrification phenomenon could be seen as a successful market-driven alternative to create income mixing and reduce segregation in central city neighborhoods. On the contrary, if results suggest displacement of the low-income population, housing policy analysts should potentially control housing renovation and influx of high-income migrants into low-income neighborhoods in order to reduce income and social segregation.

According to the results of this paper, gentrification appreciates the housing prices in every percentile of the distribution, but this appreciation is lower in the lower tail than in the upper tail. Assuming a monotonic relationship between income and housing prices, the results suggest that gentrification does

displace the low-income population, but the influx effect of mid- and high-income households is greater than the displacement effect. These results support findings obtained by qualitative analyses, but they differ from the conclusions of most econometric studies where no evidence of displacement is found. Nevertheless, mixed-income communities can be created if the influx of high-income households is stronger than the displacement of low-income groups.

The section below defines gentrification and explains the identification strategy and the econometric models. Section 2.3 describes the data used for testing the model and section 2.4 presents an analysis of the results. Section 2.5 concludes and provides some policy implications of the analysis.

2.2 Gentrification definition and identification strategy

2.2.1 Gentrification definition

One of the problems associated with empirical models of urban renewal is constructing an appropriate measure by which to define gentrified neighborhoods. There are different definitions of urban renewal based on housing price changes or changes in household status (household size, structure, income or education). Since the process of urban renewal is complex, it is not possible to include all of the potential neighborhood changes in a single definition. Freeman (2005) defines gentrification using five dimensions: location, median household income, housing construction, education attainment and housing prices. Hammel and Wyly (1996) emphasize new upscale housing construction, but also consider the replacement of low-income populations by the middle or upper classes. Similarly Clay (1979) and Helms (2003) emphasize that the gentrification and urban renewal phenomenon is a mixture of two forces: an increase in housing renovation, and the influx of mid- and high-income households to low-income neighborhoods.[1]

Gentrification in this paper is understood as a "neighborhood change" phenomenon with the presence of the two forces described by Clay (1979) and Helms (2003). The increase in housing renovation is measured by

[1]The definition of gentrification varies in the literature. While some authors include demographic trends in the definition, some others decide to link it only to changes in family income. Lees and Ley (2008) define gentrification as the "third model" of urban regeneration in which the main driver is a specific public policy, a phenomenon that has been observed in London with the government improvement grants, and in New York with the Urban Homesteading Program. McKinnish et al. (2010) define gentrified neighborhoods as those neighborhoods that had an increase in the median family income from 1990 to 2000 of more than US$10,000 dollars. They believe that by including demographic trends on the gentrification definition, the definition will determine the results of the gentrification studies. Brueckner and Rosenthal (2009) include the age of the housing stock in gentrified neighborhoods as the main determinant of gentrification because neighborhoods with older housing stock are more prompted to be gentrified. The existence of high-income households in central and low-income neighborhoods is also explained by the existence of natural and historic amenities (Brueckner et al., 1999), the choice of the transportation model (LeRoy and Sonstelie, 1983) or fiscal explanations such as the redistributive central city taxation for the improvement of public goods (Nechyba and Walsh, 2004). The College of Urban Planning and Public Affairs of the University of Illinois at Chicago develops a gentrification index where the communitiy areas of the city are classified between 13 and -13, scoring 13 the community areas with the most factors associated with gentrification. The variables considered are median family income, % families below poverty, median house value, % owner-occupied housing, race/ethnicity, % children age 5-19, % elderly, % managers and professionals, % adults with college education, % children enrolled in private schools and % of female-headed households with dependent children under age 18.

the amount of building permits approved in the neighborhood. The influx of mid and high-income households is measured by income change from 1990 to 2000, weighted by the proportion of migrants in both years. Gentrified neighborhoods are then defined as those neighborhoods that satisfy the three following conditions:

1. They belonged to the three lowest income quintiles in 1990.
2. They had a number of building permits for residential alterations from 1993 to 2000 greater than the median number of building permits approved in the city.[2]
3. Their income growth from 1990 to 2000, weighted by the proportion if immigrants, was greater than the median for the city.[3]

Figures 2.1 and 2.2 show the low-income neighborhoods (condition 1) that fulfill conditions 2 and 3, respectively. The combination of these two conditions defines gentrified neighborhoods. Figure 2.3 shows the areas of the city experiencing gentrification. The first cluster is observed in neighborhoods that are located at the West of the Loop including West Town, Logan Square, Near West Side and Near North Side. The second cluster in the far north side is formed by the neighborhoods of Uptown, Lakeview, Albany Park and Rogers Park. Finally, the third cluster is observed in the south with neighborhoods such as Grand Boulevard, Woodlawn, Kenwood, Oakland, Englewood, Armour Square, Douglas, Hyde Park, Washington Park, Fuller Park and Chatham.

Some of the neighborhoods located in the west were industrial neighborhoods that had their warehouses transformed into residential flats during the 1990s (Henderson, 2007). In the north, Uptown is considered one of the most diverse neighborhoods in Chicago and has been a focus of urban revitalization since 1968 when Truman College was constucted. In the 1990s, the percentage of lots converted into condos increased by 102%, although it is still considered a diversified neighborhood with 42% white, 21% black, and 20% Hispanic (Henderson, 2007). On the south side, the increase in immigrant income is stronger than housing renovation. Most of the housing renovation was caused by redevelopment of public housing, with programs such as HOPE VI in the Oakland and North Kenwood neighborhoods. Although this renovation was considered in the gentrification definition, most of these public housing projects were demolished at the beginning of the 2000s by the "Plan for Transformation" developed by the Chicago Housing Authority. In the 1990s, the city of Chicago designated the south lakefront as a "conservation area" facilitating new investments in city neighborhoods closer to downtown (Pattillo, 2007).[4]

[2]Building permit information is provided by the Chicago Housing Authority. Permits are classified into eight different types: additions, alteration existing usage, alteration using usage, demolition, miscellaneous or revisions, new construction, repairs general and repairs by order of the building. Only alterations to residential dwellings are considered.

[3]The proportion of immigrants in 1990 and 2000 is measured by the proportion of households in the neighborhood that were not living in the same house five years before. This proportion is multiplied by the median family income of the neighborhood and the income changes from 1990 to 2000 are calculated.

[4]The "conservation area" status allows the residents of the area to work with the local public authorities in the development

2.2.2 Identification strategy: specification of the empirical models

The effect of gentrification on the price premium distribution can be compared to the effect of a treatment on an outcome, where the treated group is the gentrified neighborhoods and the control group is the non-gentrified neighborhoods. However, in this case the treatment is not completely exogenous because of the existence of simultaneity between the level of income of a neighborhood and its housing prices. Although the distribution of housing prices used in the dependent variable is drawn using housing prices from 2005 (post-gentrification), high income neighborhoods are more likely to have higher housing prices and lower probability of being gentrified. Moreover, neighborhoods with higher housing prices were likely to have high income in the previous period. This simultaneity between the outcome (housing prices) and the definition of the treated variable (gentrification) causes endogeneity problems that bias results.

In order to address this endogeneity, we need a valid instrumental variable (IV) that not only explains the gentrification process but also is unrelated to the appreciation of housing prices in 2005. This valid IV should be uncorrelated to housing prices, although it could be correlated to housing characteristics and other covariates used to explain the appreciation of prices. Chicago is divided in 50 ward offices, each of them represented by an Alderman. The Aldermen are members of the city council and take decisions about the use of city funds and the city ordinances. Usually, for the approval of building permits, citizens apply to their corresponding ward, and the Alderman processes the information and passes it to the Department of Buildings for the final approval. Depending on which ward the neighborhood is located, the building permit approval could be faster or slower. The instrument for gentrification on this paper is the proximity of a neighborhood to a ward office. Not only the approval of building permits depends on the ward the neighborhood belongs, but also the ward office is more influenced by neighborhoods that are closer by than neighborhoods that are farther away.

Figure 2.4 shows the location of the 50 ward offices in Chicago and the neighborhoods that were gentrified in 1990s. The correlation between gentrified neighborhoods and the location of ward offices is stronger in the north and west, than in the south. Some of the ward offices are located in the far south of the city, which is mainly industrial. The validity of the instrument is tested using the Durbin-Wu-Hausman test (Durbin, 1954; Wu, 1973; and Hausman, 1978), and the null hypothesis of obtaining consistent estimates under OLS is rejected[5]

The distribution of the housing price premium is defined as the appreciation of housing prices in 2005 over their assessment values of 2000. The problem with using assessment values to define the price premium is that high-value dwellings have lower assessment values than low-value dwellings (McMillen, 2011), biasing

of new conservation plans for the neighborhood directly influencing the urban renovation process.

[5]I use the Stata code developed by Baum et al. (2007)

the gentrification effects on the price appreciation. I calculate the median of the assessment ratio in 2000 for each neighborhood and categorize the neighborhoods by quartiles depending on their ratio level. These assessment ratio quartiles are included as control variables in the quantile regressions to reduce bias.

I use parametric and non-parametric quantile regressions to test the effect of gentrification in different percentiles of the distribution. The parametric or conventional quantile regression assumes that the gentrification variable is exogenous. The model is specified as follows:

$$(\beta_\tau, \alpha_\tau) = argmin_{\beta,\alpha} \sum \rho_\tau \left(P_{ij} - X_i\beta_1 - Y_j\beta_2 - G_j\alpha\right), \tag{2.1}$$

where P_{ij} is the log of the premium of the price of house i located in neighborhood j in 2005 over its assessment value in 2000, G_j is a dummy variable with a value of one if the neighborhood j was gentrified. Y_j is a matrix of controls at the neighborhood level such as the level of income in 1990 and the assessment ratio quartiles for 2000. Finally, X_i is a matrix of covariates composed of the structural housing characteristics, distance variables and geographical areas fixed effects. The regression is estimated at different levels of the housing price premium distribution, and coefficients are reported for percentiles $\tau = 0.05$, $\tau = 0.50$ and $\tau = 0.95$.

To correct for the bias generated by the endogeneity of the gentrification definition, I use the methodology developed by Abadie et al. (2002) to estimate quantile treatment effects (QTE) with conditional endogenous treatments. The model is defined as follows:

$$(\beta_\tau, \alpha_\tau) = argmin_{\beta,\alpha} \sum \kappa(G, Z, X)\rho_\tau \left(P_{ij} - X_i\beta_1 - Y_j\beta_2 - G_j\alpha\right), \tag{2.2}$$

where $\kappa(G, Z, X) = 1 - \frac{G_j(1-Z_j)}{Pr(Z=1|X_i)} - \frac{(1-G_j)Z_j}{Pr(Z=1|X_i)}$. The instrument Z is a binary variable which is constructed using the proximity of the neighborhood to an Alderman's ward office. When $G_j = Z_j$, κ is equal to one, and the parameter α is the same as when the treatment is exogenous; otherwise κ is negative. In order to avoid using negative weights, $\kappa(.)$ is transformed to $\kappa_v = E[\kappa(G, Z, X)]$, which is a nonnegative conditional probability.

Finally, the third model specification accounts for the presence of spatial autocorrelation between housing units. The housing price of a specific dwelling could be affected by the prices of properties located in close proximity. The kernel weighted quantile regression considers the nonlinearities in the quantile regression caused by an unknown spatial structure in the model. The explanatory variables are weighted with weights defined by the kernel density function (McMillen, 2010). The kernel used is the Epanenchnikov kernel density

function defined as:

$$K(d) = \frac{3}{4}(1 - d^2) * I(|d| < 1), \tag{2.3}$$

using distance to the city center, d, as the weighted variable. The model specification is the following:

$$(\beta_\tau, \alpha_\tau) = argmin_{\beta,\alpha} \sum w_i(d)\rho_\tau \left(P_{ij} - X_i(d_i - d)\beta_1 - Y_j(d_i - d)\beta_2 - G_j(d_i - d)\alpha\right), \tag{2.4}$$

where $w_i(d)$ is the weighting function defined by the kernel function, $w_i(d) = K((d_i - d)/h)/h$. The bandwidth or window size, h, is chosen to have a smooth quantile function: a large h produces too much smoothing, and a small h introduces too much variability relying on too few observations (Koenker, 2005, p. 223). According to McMillen (2011), there is no significant difference between estimating the nonparametric quantile regression by directly using kernel density estimations or by weighting the parametric quantile regression by a kernel density function. Figure 2.5 shows the kernel density functions for the whole sample as well as for a sample that includes only the neighborhoods that belonged to the three lowest income quintiles in 1990, respectively.

The models in equations 2.1, 2.2 and 2.4 are estimated considering both (a) all the housing transactions in the city of Chicago and (b) only the housing transactions of neighborhoods belonging to the three lowest income quintiles in 1990. The former allows the comparison of housing price appreciation between gentrified neighborhoods and high-income stable areas located mostly at the north of the Loop. The latter compares gentrified neighborhoods only with similar neighborhoods that had the same level of income before the gentrification process.

2.3 Description of the data

The demographic and income variables used in the model were obtained from the Neighborhood Change Database (NCDB) provided by Geolytics. The data set contains social, demographic, economic and housing data by census tract, county and state levels for the U.S. Individual housing transactions, including their characteristics, price, and month and year of sale were provided by the Illinois Department of Revenue and compiled by McMillen (2008). The housing information is available from January 1983 until December 2006. In this study, the housing sales for 2005 are used and compared to their assessment values of 2000. Year 2005 is chosen because it is the year before the beginning of the housing crisis. Although it would be interesting to observe the effects of gentrification over a longer period of time, choosing housing prices from years after 2005 would necessarily include the housing crisis effects of 2007 in the estimations, which would

cause difficulty in isolating gentrification effects from crisis effects.

The Assessor's Office conducts assessments in Cook County, and assessments should be 16% of the value of the property. . However, in 2009, the target assessment was changed to 10% because most of the properties were under-assessed (Weber and McMillen, 2010). In this paper, I use the assessment values from 2000 for housing sales of 2005. Additionally, I calculate the assessment ratio by neighborhood in 2000 to control for non-uniform assessment values for low- and high-value properties.

There are two units of analysis in the econometric models: the first, used to define gentrified neighborhoods, is the neighborhood level measured by census tracts. Census tracts are the smallest unit of analysis provided by the Census and are the best proxy for measuring neighborhood effects (Tatian, 2003). The second, used for the quantile regression analysis, is individual housing prices. By using "individual" observations instead of "aggregate" variables by neighborhood, it is possible to analyze the behavior of the price distribution.

Table 2.1 shows a description of the main variables including the number of building permits approved for residential alterations and the changes in income from 1990 to 2000 weighed by the proportion of migrants. The total number of individual housing transactions is 16,103 distributed in 738 city tracts.[6] Statistics are presented for the whole sample, the subsample of gentrified neighborhoods and the subsample of non-gentrified neighborhoods. The differences in samples and their corresponding t-statistic are shown in columns E and F. The gentrified neighborhoods account for 12.19% of the total city neighborhoods and 26.78% of the neighborhoods belonging to the three lowest income quintiles in 1990.

Differences in means between gentrified and non-gentrified neighborhoods are significant and contain the expected signs for most of the variables considered. With the exception of the structural characteristics of the properties, most of these differences are statistically significant at the 95% level when comparing the gentrified neighborhood sample with the two non-gentrified neighborhood subsamples (neighborhoods in the whole city and neighborhoods belonging only to the three lowest quintiles in 1990).

Properties in gentrified neighborhoods have, on average, higher prices than in non-gentrified neighborhoods, and this difference is significant when comparing them to the prices of all the neighborhoods in the city as well as the prices of only the neighborhoods from the low income quantiles in 1990. Their assessment value was also higher in 2000, suggesting that the appreciation of housing values started before 2000 and continued to 2005 when the housing prices were reported.

The variables used to define gentrification also have higher values, on average, in gentrified than in non-gentrified neighborhoods. The average number of permits authorized for housing renovation from 1993 to

[6]Only tracts with housing transactions in 2005 were included in the analysis. The total number of tracts in the city of Chicago are 1,848.

2000 was 30.37. This number decreases to 19.89 in non-gentrified neighborhoods belonging to the whole city, and 8.97 in non-gentrified neighborhoods belonging to the lowest income quintiles in 1990. The increase in income weighted by the number of migrants is also greater in gentrified neighborhoods, showing an increase of 2.01 on average, while this increase is only 0.85 in the non-gentrified neighborhoods.

Gentrified neighborhoods are also closer to the CBD on average and have properties older than the other neighborhoods in the city, but newer than the properties of neighborhoods belonging to the lowest income quintiles in 1990. According to Helms (2003), Mendelsohn (1977) and Chinloy (1980), building age increases the probability of housing renovation. Then we could expect gentrified neighborhoods to have older properties than non-gentrified neighborhoods. Other housing structural characteristics such as area built, number of bedrooms, whether the property has central air, a basement or attic, do not have significant differences when comparing the means between gentrified and non-gentrified neighborhoods.

2.4 Analysis of the results

Results for the conventional quantile regression, QTE estimates and weighted kernel quantile regressions are shown in table 2.2. Whether the whole sample is used, or only the neighborhoods belonging to the three lowest income quintiles in 1990, conventional quantile regression estimates show that housing prices in gentrified neighborhoods appreciate faster than in non-gentrified neighborhoods, but this appreciation is much larger above the median than below it. The premium of the .95 quantile is 30 percent larger in gentrified neighborhoods when compared to the whole sample, while this figure is only 10 percent in the .05 quantile of the premium. In the case where the gentrified neighborhoods are compared only to neighborhoods that belonged to the three lowest income quintiles in 1990, gentrification increases the premium by 28 percent in the .95 quantile, while this increase is only 14 percent in the .05 percentile.

Quantile regression coefficients usually do not have a causal interpretation, and they only provide a comparison of the housing price premium distribution for gentrified and non-gentrified neighborhoods (Abadie et al., 2002). The QTE estimates correct for this possible endogeneity and are shown in column B. I used the methodology proposed by Froelich and Melly (2010) for the implementation of the QTE and for the estimation of $\kappa(G, Z, X)$. As mentioned previously, the gentrification dummy is instrumented using the proximity of a neighborhood to a ward office.[7]

QTE estimates support the results obtained by the conventional quantile estimates: properties in gentrified neighborhoods appreciate faster than properties in non-gentrified neighborhoods from 2000 to 2005.

[7]For the estimation of the QTE, the instrumental variable must be a binary variable. Thus, a neighborhood receives a value of 1 if it is adjacent to a neighborhood where a ward office is located and a value of zero otherwise.

However, two differences are observed when the QTE estimates are compare to the conventional quantile regression estimates. First, when the entire sample is considered, the difference in appreciation between the lower and the upper tail of the price premium distribution is not economically significant. While the effect of gentrification in the .95 of the premium is 62 percent, this effect is 60 percent in the lower tail. Second, when gentrified neighborhoods are compared only to low-income neighborhoods in 1990, the differences between appreciation in gentrified and non-gentrified neighborhoods in the lower tail of the premium distribution is not statistically significant, suggesting that low-value dwellings in gentrified neighborhoods have a prices appreciation of low-value dwellings similar to the appreciation of low-value dwellings located in low-income neighborhoods that were not gentrified.[8]

Finally, model 3 shows the kernel weighted quantile estimates correcting for the spatial dependence of housing prices. The standard errors in every percentile are similar to the standard errors obtained with the conventional quantile regression as well as the goodness-of-fit of the regression. However, the estimates are greater in magnitude and statistically significant at the 95% level, suggesting that the appreciation of housing prices is correlated in space. For example, the appreciation of a property increase the likelihood that other nearby properties will appreciate. According to the estimates of column C, properties in gentrified neighborhoods appreciate 5 percentage points more in the lower tail of the distribution when compared to the conventional quantile regression estimates of column A. This difference is reduced to 2 percentage points in the middle and 3 percentage points in the upper tail of the premium distribution.

The spatial dependence is stronger in the lower tail when comparing gentrified neighborhoods only with low-income neighborhoods in 1990. Properties in gentrified neighborhoods appreciate by 9 percentage points more when considering spatial dependence of the housing price premia.

Table 2.2 also reports some of the neighborhoods and housing characteristics included in the regressions. In addition to the gentrification variable, the median of the assessment/price ratio of 2000 for each neighborhood is also included to account for differences in the assessment process between low- and high-value dwellings. According to the coefficients of the conventional quantile regression and the kernel weighted regression, properties in neighborhoods with a greater assessment ratio in 2000 appreciate faster than properties in neighborhoods with low assessment ratios. The QTE estimates show a different pattern with very low evidence of impact of the assessment ratio in 2000 in the appreciation of housing prices in 2005.

As expected, properties located closer to the city center (CBD) appreciate faster than properties located farther away, suggesting the existence of housing revitalization closer to the CBD. Surprisingly, and as

[8]The standard errors of the QTE estimation are greater than the standard errors of the conventional quantile regression, suggesting that the instrument does not completely explain the endogeneity of the gentrification definition. However, the instrument is still exogenous and its theoretical justification is still valid.

another indicator of the existence of revitalization, the .05 quantile of the housing premium is more affected by the proximity to the CBD than the .95 quantile. For example, the kernel weighted estimate (standard error) of the effect of distance from the CBD is 12.1 percent (.014) for the .5 quantile, while the corresponding estimate for the .95 quantile is 7.3 percent (0.008).

Older properties do not appreciate faster than newer properties. Even if this coefficient were significant in previous studies of housing renovation (see Helms, 2003), this characteristic is not economically significant in explaining the distribution of the housing price premium. Although some of the coefficients in the different specifications are negative and significant, the magnitude is too small to have an economic interpretation.

Although the data set used for this analysis does not provide information about the income and demographic characteristics of the homeowners, inference can be made when assuming a monotonic relationship between housing prices and level of income. In other words, the results of this analysis can provide some insight about the displacement of the low-income population from gentrified neighborhoods if we assume that low-income households live in low-value dwellings, and high-income households live in high-income dwellings. If the low-value dwellings appreciate with gentrification, low-income populations are displaced from gentrified neighborhoods.

Nevertheless, because this appreciation is lower in the lower tail of the housing price premium distribution than in the upper tail, the influx of high-income migrants is stronger than the low-income population displacement, suggesting that the population in the gentrified neighborhood does not decrease, and some mixed-income communities are created. By analyzing demographic characteristics from a post-gentrification period, we can further investigate the creation of mixed-income communities. However, because the last Census data available are from 2000, this paper cannot include an analysis of population change from the 1990s to 2005.

2.5 Conclusions

This analysis attempts to measure the effects of gentrification by evaluating the appreciation of housing prices after five years of the gentrification process. Data from a longer period of time were not used because the prices would show the effects of the housing crisis, thus making it difficult to isolate the previous effects of gentrification from the effects of the crisis.

Whether or not the gentrification definition is endogenous, or whether or not the housing prices are spatially correlated, estimates suggest that properties located in gentrified neighborhoods appreciate faster than properties in non-gentrified neighborhoods, but this appreciation is lower in the lower tail of the price

premium distribution than in the upper tail.

By assuming a monotonic relationship between housing prices and income, the results of this study can be used to analyze the effects of gentrification in terms of population displacement. If gentrification appreciates the prices of low-value dwellings, the low-income households would be displaced from gentrified neighborhoods, increasing income segregation in the city. However, the appreciation of high-value dwellings is greater than that of low-value dwellings, suggesting that the influx of mid- and high-income populations is stronger than the displacement of low-income population, resulting in mixed-income communities being created through the gentrification process.

The results of this paper challenge the notion of the negative effects of gentrification on housing segregation. If, to some extent, gentrification creates mixed-income communities when the mid- and high-income gentrifiers move to the neighborhood, housing segregation in the city decreases. However, results might be different if more aggregated locations are analyzed. Chicago is still experiencing high levels of segregation at the inter-neighborhood level, and the displacement of the low-income population from gentrified neighborhoods is a trend that must be watched carefully as a trigger for segregation. Racial and socioeconomic segregation can be observed when comparing the northern side of the city to the southern side. Further analysis is required for a deeper understanding of this issue.

This paper provides important insights into the consequences of gentrification, not only for the city of Chicago, but also for every metropolitan area that has experienced gentrification processes. If high-value dwellings are more appreciated than low-value dwellings in gentrified neighborhoods, gentrification could be used as a market-driven housing policy. In addition, it could be compared to housing programs that aim to reduce segregation and increase housing opportunities for low-income populations.

Further research is necessary to better characterize the variables associated with gentrification. Firstly, because of data constraints, the assumption of monotonicity between income and housing prices had to be employed. That is, higher-value houses are purchased by high-income populations. However, if information of ethnicity and income is provided for each housing sale transaction, this exercise can be replicated without using monotonicity assumptions and can test if, in effect, low income populations are not displaced from gentrified neighborhoods. Secondly, if the gentrification definition is endogenous, even after using different periods of time to generate a causal relationship, a better instrument of gentrification could be employed. The higher standard errors in the QTE estimates suggest that the instrument is not decreasing the endogeneity of gentrification with respect to the appreciation of housing prices, even if theoretically, the location of ward offices is exogenous to the dependent variable.

As a robustness check, further work will replicate the results obtained in this paper using different defini-

tions of gentrification and a different definition for the housing price premium. Characteristics of gentrified neighborhood such as the proportion of the Hispanic population in the neighborhood, the proximity of the neighborhood to high-income areas, and the number of projects built and demolished in the neighborhood will be included in the definition of gentrification. With respect to the housing price premium definition, the appreciation will be defined comparing the assessment values in both years (2000 and 2005) instead of assessment values in 2000 and housing prices in 2005, and comparing the quantile estimates of this paper with the OLS and 2SLS estimates using only the upper and the lower tail of the distribution. Finally, the robustness of the results will be also tested by using different instrumental variables for gentrification, such as the grid street structure of the city, or the proximity of a gentrified neighborhood to a neighborhood that was gentrified in a previous period.

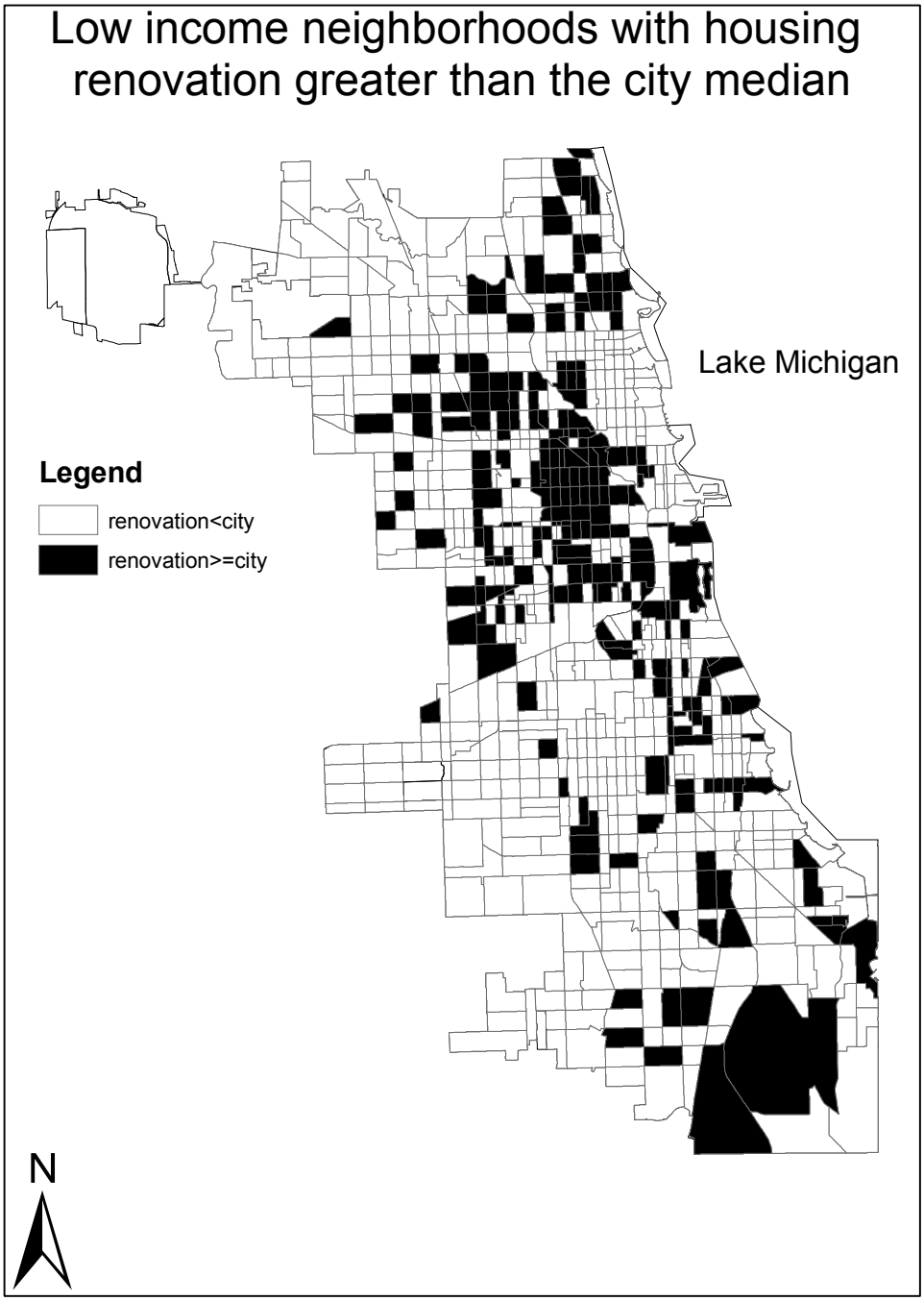

Figure 2.1: Low-income neighborhoods satisfying condition 1 and 2 (housing renovation). Neighborhoods that had a number of building permits for residential alterations greater than the median of building permits for the city.

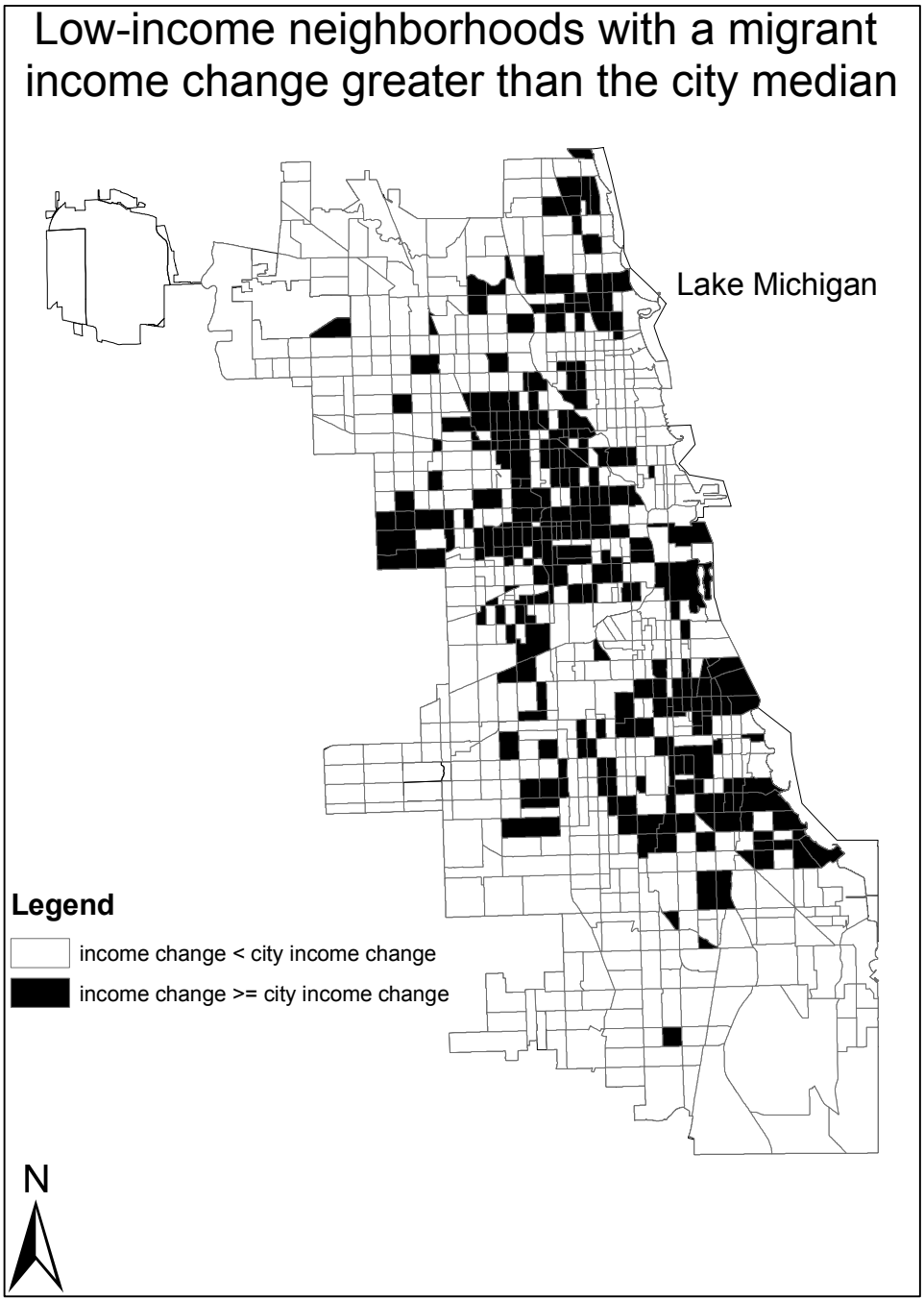

Figure 2.2: Low-income neighborhoods satisfying condition 1 and 3 (migrant income). Their income growth from 1990 to 2000, weighted by the proportion if immigrants, was greater than the median for the city.

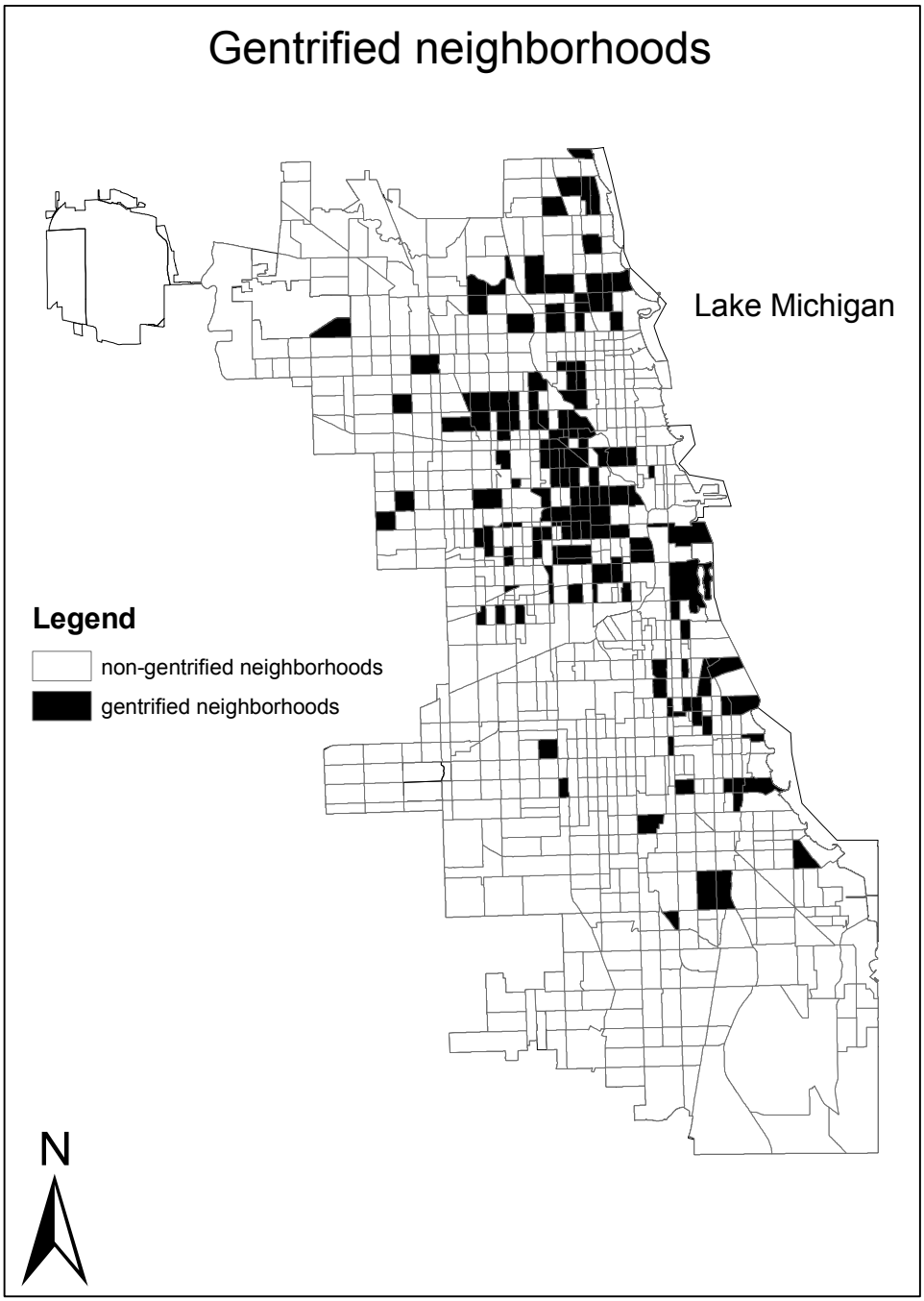

Figure 2.3: Gentrified neighborhoods that satisfy the three conditions of gentrification: combination of housing renovation and change in migrant income.

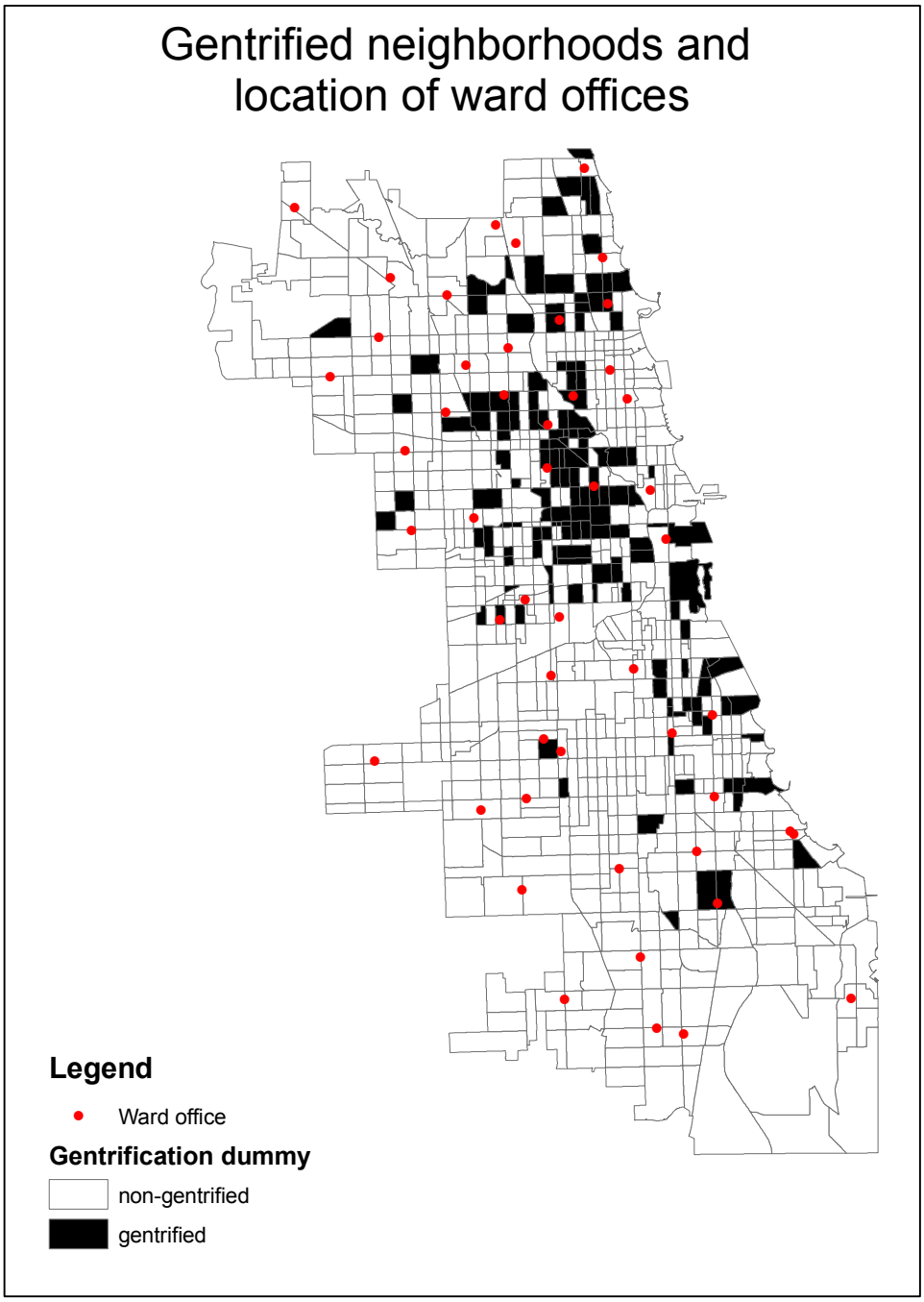

Figure 2.4: Location of ward offices and gentrified neighborhoods.

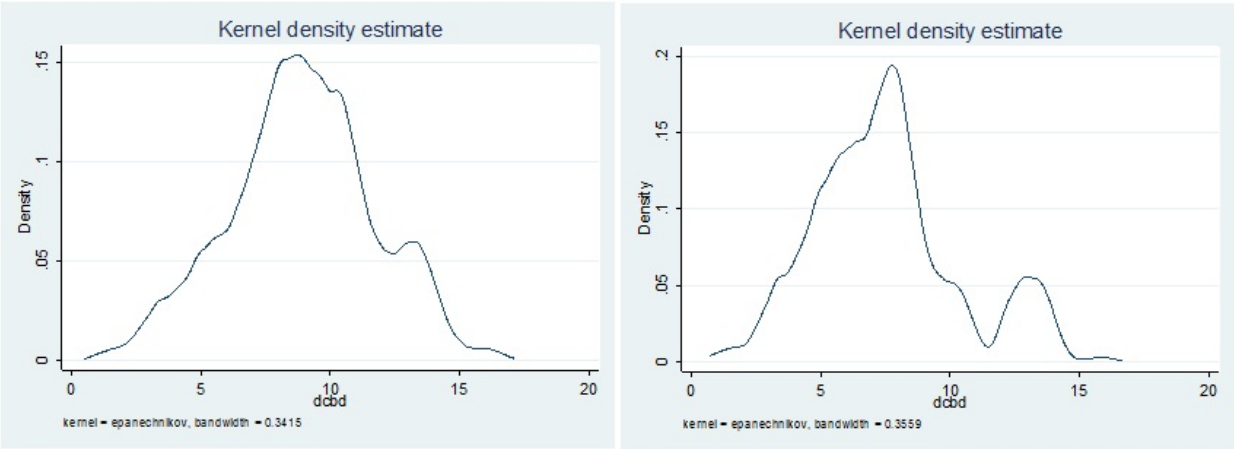

Figure 2.5: Kernel density functions. Panel a (left): kernel density using all the observations. Panel b (right): kernel function using only the properties located in the lowest income neighborhoods in 1990.

Table 2.1: Means and standard deviations (in parentheses) for the gentrified and non-gentrified neighborhoods. The columns E and F show differences in means and report the t-statistic (in brackets) for the null hypothesis of equality in means.

	Column A	Column B	Column C	Column D	Column E	Column F
	Entire sample	Gentrified neighborhoods	Non-gentrified neighborhoods	Non-gentrified neighborhoods(low income)	Diff. col [B] & col [C]	Diff. col [B] & col [D]
No. properties sold in 2005	21.82	12.05	23.18	14.62		
	(26.4)	(11.28)	(27.59)	(17.27)		
Price	310,212.60	405,432.30	298,017.80	205,660.60	-107,414.50	-199,771.70
	(212,401.40)	(177,340.90)	(214,584.60)	(111,420.70)	[-4.53]	[-13.13]
Assessment values in 2000	15,343.99	18,058.54	14,972.25	8,762.47	-3,086.29	-9,296.07
	(12,451.97)	(9,321.20)	(12,785.37)	(4,944.65)	[-2.20]	[-12.78]
Premium	294,500.00	385,975.50	282,819.90	196,774.30	-103,155.60	-189,201.20
	(200,560.40)	(168,244.40)	(202,503.60)	(107,645.80)	[-4.61]	[-12.97]
Housing renovation	21.17	30.37	19.89	8.97	-10.48	-21.40
(building permits 1993-2000)	(24.28)	(18.14)	(24.76)	(8.39)	[-3.87]	[-16.13]
Changes in income (1990-2000)	0.99	2.01	0.85	0.86	-1.16	-1.15
weighted by migration	(1.76)	(1.83)	(1.70)	(1.93)	[-5.99]	[-5.06]
Distance to CBD	6.93	5.14	7.18	6.33	2.04	1.19
	(3.02)	(2.08)	(3.05)	(2.53)	[6.15]	[4.09]
Age of properties	77.40	89.70	75.66	88.09	-14.04	-1.61
	(28.78)	(27.05)	(28.58)	(24.46)	[-7.73]	[-0.54]
Log built area	7.11	7.21	7.10	7.02	-0.11	0.19
	(0.31)	(0.32)	(0.30)	(0.30)	[-3.02]	[-5.02]
No. bedrooms	2.94	3.11	2.92	2.85	-0.19	-0.26
	(0.75)	(0.76)	(0.76)	(0.85)	[-2.10]	[-2.62]
Central air dummy	0.10	0.08	0.10	0.04	0.02	-0.04
	(0.29)	(0.26)	(0.29)	(0.19)	[0.46]	[-1.73]
Basement dummy	0.79	0.82	0.79	0.71	-0.03	-0.11
	(0.38)	(0.36)	(0.39)	(0.43)	[-0.68]	[-2.23]
Attic dummy	0.35	0.36	0.35	0.30	-0.01	-0.06
	(0.46)	(0.46)	(0.46)	(0.44)	[-0.17]	[-0.96]
No. of observations (tracts)	738	90	648.00	336.00		

Table 2.2: Quantile regression estimates. Dependent variable: log of the housing price premium. The instrument for the QTE estimation is proximity to a ward office, and the weighted variable in the kernel quantile regression is distance to the CBD.

	Conventional Quantile Model 1			**QTE Estimation Model 2**			**Kernel Quantile Model 3**		
	Using all the observations in the data set (N= 16,103)								
	$\tau = 0.05$	$\tau = 0.5$	$\tau = 0.95$	$\tau = 0.05$	$\tau = 0.5$	$\tau = 0.95$	$\tau = 0.05$	$\tau = 0.5$	$\tau = 0.95$
Gentrification dummy	0.104***	0.127***	0.304***	0.606***	0.486***	0.621	0.152***	0.157***	0.332***
	(0.030)	(0.016)	(0.034)	(0.149)	(0.101)	(0.361)	(0.038)	(0.013)	(0.023)
AV/Price ratio (2000)	0.038***	0.018***	0.017*	-0.131*	-0.051	-0.064	0.021*	0.008**	-0.012
	(0.010)	(0.003)	(0.005)	(0.064)	(0.034)	(0.103)	(0.01)	(0.003)	(0.007)
DCBD	-0.092***	-0.082***	-0.084***	-0.139	-0.096**	-0.088	-0.121***	-0.074***	-0.073***
	(0.011)	(0.003)	(0.007)	(0.078)	(0.034)	(0.116)	(0.014)	(0.005)	(0.008)
Age	-0.003***	0.000	0.001***	-0.006*	-0.002	-0.001	-0.003***	-0.001***	0.001*
	(0.000)	(0.000)	(0.000)	(0.002)	(0.002)	(0.004)	(0.000)	(0.000)	(0.000)
R2	0.363	0.462	0.5021				0.276	0.3945	0.4224
Housing characteristics		*yes*			*yes*			*yes*	
Dummies for geog. areas		*yes*			*yes*			*yes*	
	Using only the observations from neighborhoods belonging to the three lowest income quintiles in 1995 (N=5,997)								
	$\tau = 0.05$	$\tau = 0.5$	$\tau = 0.95$	$\tau = 0.05$	$\tau = 0.5$	$\tau = 0.95$	$\tau = 0.05$	$\tau = 0.5$	$\tau = 0.95$
Gentrification dummy	0.141*	0.152***	0.283***	0.177	0.306***	0.475**	0.235***	0.129***	0.258***
	(0.047)	(0.015)	(0.046)	(0.316)	(0.063)	(0.163)	(0.059)	(0.019)	(0.027)
AV/Price ratio (2000)	0.010	0.020***	-0.006	-0.291**	-0.064	-0.062	0.045*	0.042***	-0.009
	(0.016)	(0.005)	(0.009)	(0.107)	(0.039)	(0.065)	(0.022)	(0.006)	(0.009)
DCBD	-0.136***	-0.131***	-0.149***	-0.093	-0.113	-0.126*	-0.164***	-0.143***	-0.172***
	(0.023)	(0.008)	(0.015)	(0.074)	(0.046)	(0.060)	(0.036)	(0.011)	(0.017)
Age	0.000	0.000	0.001**	-0.002	-0.001	0.000	0.000	0.001*	0.002***
	(0.001)	(0.000)	(0.000)	(0.002)	(0.002)	(0.001)	(0.001)	(0.000)	(0.000)
R2	0.249	0.3907	0.4774				0.2298	0.3322	0.4428
Housing characteristics		*yes*			*yes*			*yes*	
Dummies for geog. areas		*yes*			*yes*			*yes*	

Standard errors in parentheses. Bootstrapped standard errors for the conventional quantile regression (reps=100)
$*p < 0.05$, $**p < 0.01$, $***p < 0.001$

Chapter 3

A General Equilibrium Analysis of Rural-Urban Migration with Illegal Markets

3.1 Introduction

Since the 1950s, migration between rural and urban areas has been an important issue in developing economies. Contrary to evidence observed in developed countries, rapid urbanization in developing countries has increased the income differentials between rural and urban areas, and has influenced the levels of urban unemployment and underemployment. Non-economic conditions such as armed and social conflicts have also increased the migration flows from rural to urban areas. In Colombia, for example, 29.1% of the rural population (or 7% of the total population) suffers from displacement due to the existence of an armed conflict and illegal drugs market (Ibanez and Velez, 2008). An analysis of migration should include the non-economic factors that affect individuals' migration decisions.

Lewis (1954) and Ranis and Fei (1961) provide a model to explain economic growth based on the development of the modern industrial sector. Todaro (1976) and Harris and Todaro (1970) explain the migration decision between rural and urban areas with the existence of unemployment in cities. Several authors have extended the Harris-Todaro model. Cole and Sanders (1985), Chaudhuri (1989) and Brueckner (1990) include the informal sector in a general equilibrium analysis with rural-urban migration using different theoretical frameworks. Shapiro and Stiglitz (1984) treat urban wages as endogenous variables, giving birth to the efficiency-wage models. Layard et al. (1991) explain the migration decision as the tradeoff between higher wage differentials or lower unemployment: if the wage differential is excessive, rural-urban migration will continue until urban unemployment is sufficient.

Chaudhuri and Mukhopadhyay (2009) summarize the different extensions of the Harris-Todaro model (including the models developed by Marjit and Beladi, 1996; Gupta, 1993; and Chaudhuri, 2000). They analyze the effects of trade liberalization, subsidies given to the urban sectors and rural development on unemployment and welfare. Zenou (2011) develops a general equilibrium model with two sectors and unemployment in order to analyze the effects of decreasing unemployment benefits or subsidizing unemployment on reducing urban unemployment. However, neither the Harris-Todaro model nor any of its extensions

-which include the informal sector- are able to provide a complete explanation of the migration phenomenon when non-economic variables affect migration decisions.

In this paper, we use a different extension of the Harris-Todaro model. In the case of Colombia, non-economic variables such as violence are related to a sector that produces and exports illegal drugs. The utility of workers employed in this sector is affected negatively by the fact that they are afraid, and feel guilty about doing something illegal. This disutility received in the violence sector affects the spatial equilibrium and allocation of workers. Some of them may migrate to cities, even if the money wage received in the violence sector is greater than that in the urban sector. Under this framework, we explain the allocation decision of workers under the existence of non-economic factors.

An increase in the minimum wage in manufacturing has ambiguous effects on manufacturing labor and on violence labor, depending on the initial conditions of the economy. In some cases, a rise in the manufacturing wage increases the labor force in the city and reduces the violence sector labor. However, with this manufacturing labor increase, city unemployment grows as well; thus, policy makers face a tradeoff between decreasing violence and decreasing unemployment. In other cases, the rise in the manufacturing wage exacerbates the conditions both in cities and in rural areas: unemployment and violence labor both increase. In all cases, the initial level of violence has an inverse relationship with the changes in the violence sector, and the initial level of unemployment has an inverse relationship with the changes in unemployed labor. These results show that an analysis of the allocation of workers must consider non-economic factors when the economy includes distortions such as unemployment and violence.

Although this exercise does not use real data, the socioeconomic situation of Colombia is a good application for this theoretical model. Colombia is the number one producer of cocaine in the world, according to the United Nations Office of Drugs and Crime (UNODC). The production of illegal drugs is related to the armed conflict because the main producers of cocaine are the domestic illegal armed groups. Households in the countryside have the option to work for this illegal sector and earn higher wages than in the traditional agricultural sector, but with a higher probability of being incarcerated, kidnapped or killed. This "guilt and fear" of doing something illegal negatively affects their utility, and in some cases they decide to migrate to the cities, even knowing that earnings in the countryside are greater, and that the probability of obtaining a job in the cities is reduced because of city unemployment.

The paper proceeds as follows. Section 3.2 describes the general equilibrium framework in our version of the Harris-Todaro model with unemployment and violence, and it describes the techniques used to linearize and solve the system of equations. Section 3.4 analyzes the results under a simple case scenario where the factor shares and the elasticities of substitution are the same for both sectors. Section 3.5 provides a

sensitivity analysis using different values for the parameters of the model. Finally, section 3.6 provides some concluding remarks and discusses policy implications about the existence of an illegal sector in a developing economy with unemployment.

3.2 The general equilibrium framework

3.2.1 The basic model

This section describes a model for representing a small open economy with two sectors: a manufacturing sector and a violence sector. The violence sector is located in the rural areas, while the manufacturing sector is situated in urban areas. Workers are homogeneous and move among the two sectors until their utility is equalized.

On the other side of the market, producers maximize profits and operate in perfect competition. Manufacturing goods are imported, produced domestically, and consumed domestically, while the violence sector goods are produced domestically and exported. For trade balance, the value of manufacturing imports must be equal the value of illegal exports. As a small open economy, prices of manufacturing and violence goods are therefore fixed.

Urban areas have positive unemployment in the initial conditions of the economy, explained by the existence of a minimum wage. In response to an exogenous shock, such as an increase in teh minimum wage, unemployment levels increase or decrease depending on the movement of workers to and from the rural areas. The rural areas labor clears the market using the wage as a mechanism, but in the violence sector, the utility received by workers is not equal to the money wage. Violence workers face a disutility from being employed in an illegal activity, and this disutility depends on is related to the amount of labor allocated to the violence sector.

The model is used to analyze the effects of an exogenous change in the manufacturing sectors' minimum wage on the levels of employment in the two sectors, in the unemployed labor, and in the wages paid by the different sectors. The main interest is to analyze whether the increase in the manufacturing wage raises the level of unemployment in the cities while reducing the number of workers employed in the violence sector. The model shows how the initial conditions of the economy affect the decisions of individuals to migrate from rural to urban areas or vice versa, and it provides an explanation of the role of distortions in the migration decision.

The general equilibrium framework includes two distortions, one in each sector. The two goods in the economy are represented by a manufacturing good (M) and a violence or illegal good (V), each produced

by a different sector. The factors of production are the manufacturing labor (L_M), violence labor (L_V), manufacturing capital (K_M) and violence capital (K_V). The production function of the manufacturing and violence products are given by:

$$M = M(L_M, K_M), \tag{3.1}$$

$$V = V(L_V, K_V), \tag{3.2}$$

and the factor endowments for the whole economy, considering also the unemployed labor, L_U, are:

$$L_M + L_V + L_U = \bar{L}, \tag{3.3}$$

$$K_M + K_V = \bar{K}. \tag{3.4}$$

Both factors are assumed to be mobile, but each sector has a different wage. For their migration decision, workers react to the *effective* wages rather than the actual money wages. The effective wages consider distortions in the economy such as unemployment in the city and the "fear and guilt" in the violence sector. Equilibrium in the economy is reached when the effective earnings in each sector are equalized.

The effective manufacturing wage considers the unemployment in the cities. Defining the total city labor force (L_C) as the sum of the labor employed in the manufacturing labor and the unemployed labor ($L_C = L_M + L_U$), the probability of employment is given by the fraction $L_M/L_C \leq 1$. Assuming risk neutrality, for simplicity, the expected wage in the manufacturing sector is also the effective wage, which we then define as:

$$w_M^{\epsilon} = w_M \frac{L_M}{L_C}, \tag{3.5}$$

where $\frac{L_M}{L_C} \leq 1$.

In the violence sector, workers receive disutility because of the fear and guilt of working for something illegal. More hours working in the violence sector means a greater negative feeling and larger disutility. In these cases, in terms of utility, the effective wage they receive for being employed in the violence sector is not the monetary wage (i.e. w_V), but an effective wage (w_V^{ϵ}) that considers this disutility. This disutility depends on the amount of labor in the violence sector, L_V and so L_V appears directly in the utility function. Individuals choose L_V the amount of manufacturing product consumed domestically, M^C to maximize:

$$\mathcal{L} = U(M^C, L_V) + \delta \left(\left(\frac{L_M}{L_C} \right) w_M(\bar{L} - L_V) + w_V L_V - P_M M^C \right). \tag{3.6}$$

Utility increases with the manufacturing good consumed ($\frac{\partial U}{\partial M^C} > 0$), and it decreases with labor in the

violence sector ($\frac{\partial U}{\partial L_V} < 0$). The second argument in this utility function is not a purchased good, but rather, it reflects the disutility from fear and guilt that depends on the amount of time spent working in the violence sector. The marginal utility of income is defined by δ, and the term in parenthesis in equation 3.6 is the income constraint. Individuals receive cash income by working in the violence sector and by working in the manufacturing sector.[1] However, because labor in the cities is not fully employed, the manufacturing earnings are multiplied by the probability of employment already defined in equation 3.5, ($\frac{L_M}{L_C}$). The consumer's first order conditions are:

$$\frac{\partial U}{\partial M^C} = \delta P_M, \tag{3.7}$$

$$\frac{\partial U}{\partial L_V} = \delta \left(\frac{L_M}{L_C} w_M - w_V \right). \tag{3.8}$$

As mentioned above, in equilibrium, the effective wages in the violence and manufacturing sector are equal. Define $\phi = -\frac{\partial U/\partial L_V}{\delta} > 0$ as the marginal disutility from fear and guilt from one unit of L_V (converted into a monetary measure when divided by the marginal utility of income). Rearranging terms in equation 3.8, the spatial equilibrium is achieved when:

$$\frac{L_M}{L_C} w_M = w_V^{\epsilon} = w_V - \phi. \tag{3.9}$$

The elasticity of production in the manufacturing and the violence labor are defined as follows:

$$\sigma_M = \frac{d(K_M/L_M)/(K_M/L_M)}{d(w_M/r)(w_M/r)}, \tag{3.10}$$

$$\sigma_V = \frac{d(K_V/L_V)/(K_V/L_V)}{d(w_V/r)(w_V/r)}. \tag{3.11}$$

Perfect competition and constant returns to scale imply zero profit conditions given by equations 3.12 and 3.13:

$$P_M M = w_M L_M + r K_M. \tag{3.12}$$

$$P_V V = w_V L_V + r K_V. \tag{3.13}$$

The manufacturing imports are defined as M^I. The total manufacturing consumption, M^C, is then defined as the sum of manufacturing imports and manufacturing product domestically produced:

$$M^C = M + M^I. \tag{3.14}$$

[1] All workers are homogeneous. Because we do not know which one is working in the manufacturing sector, and which one in the violence sector, the utility calculation effectively assumes that every person works part-time in each sector.

We assume a small open economy, so prices P_M and P_V are fixed. We set $P_V = P_M$ to fixed world prices and treat this fixed relative price as numeraire. Trade balance is characterized by:

$$P_V V = P_M M^I. \tag{3.15}$$

As noted by equation 3.6, consumers only consume manufacturing product (M^C) because the violence product is totally exported. Hence, we do not need to define the elasticity of substitution in utility, because only one good is considered in the utility of consumers. The equations above represent an economy with two sectors, homogeneous labor and capital, and unemployment and violence as distortions. In the next section, we linearize the model to create a linear system of equations that allows us to analyze the effects of increasing the manufacturing wage on employment and prices.

3.2.2 Linearization of the basic model

Changes in the total city labor force can be derived by defining $\alpha = L_U/L_C$ as the proportion of city workers unemployed, and $(1-\alpha)$ as the proportion of city workers employed in the manufacturing sector. The new linearized equation is given by:

$$\widehat{L}_C = (1-\alpha)\widehat{L}_M + \alpha\widehat{L}_U, \tag{3.16}$$

where the hat represents proportional changes of the variable (i.e. $\widehat{L}_C = \frac{dL_C}{L_C}$).

Taking logs at both sides of equation 3.5 and total differentiating the new log equation, changes in the expected manufacturing wage are given by:

$$\widehat{w}^{\epsilon}_M = \widehat{w}_M + \widehat{L}_M - \widehat{L}_C. \tag{3.17}$$

Similarly, changes in the expected violence wage are found by taking logs of both sides and total differentiating equation 3.9:

$$\widehat{w}^{\epsilon}_V = \psi\widehat{w}_V - \eta\widehat{L}_V, \tag{3.18}$$

where $\psi = \frac{w_V}{w^{\epsilon}_V}$ is just the ratio of the violence wage and the effective wage, and $\eta = \frac{L_V}{w^{\epsilon}_V}\phi'$ is the elasticity of disutility with respect to L_V.[2]

In equilibrium, the effective wage in the manufacturing sector must be equal to the effective wage in the

[2]The parameter $\phi > 0$ because it is defined as the marginal disutility generated by an extra hour worked in the violence sector. From the consumers' first order conditions, this disutility is defined as $\phi = w_V - w^{\epsilon}_V$. By taking derivatives with respect to L_V we get $\frac{\partial\phi}{\partial L_V} = -\frac{\partial w^{\epsilon}_V}{\partial L_V} = \phi' > 0$, given that $\frac{\partial w^{\epsilon}_V}{\partial L_V} < 0$. Replacing ϕ' in η we get $\eta = \frac{L_V}{w^{\epsilon}_V}\frac{\partial\phi}{\partial L_V} = \frac{L_V}{w^{\epsilon}_V}(-\frac{\partial w^{\epsilon}_V}{\partial L_V}) > 0$.

violence sector. Then, equations 3.17 and 3.18 can be combined to describe the spatial equilibrium:

$$\widehat{w}_M^{\epsilon} = \widehat{w}_V^{\epsilon}. \tag{3.19}$$

In the specific case of manufacturing, we differentiate the manufacturing production function of equation 3.1 to get:

$$dM = M_{L_M} dL_M + M_{K_M} dK_M, \tag{3.20}$$

where M_{L_M} and M_{K_M} are first derivatives of M with respect to L_M and K_M, respectively. Dividing everything by M and multiplying and dividing the first and second terms of the RHS by L_M and K_M, respectively:

$$\widehat{M} = \frac{L_M M_{L_M}}{M} \widehat{L}_M + \frac{K_M M_{K_M}}{M} \widehat{K}_M. \tag{3.21}$$

The firm's first order conditions imply that $w_M = P_M M_{L_M}$ and $r = P_M M_{K_M}$. We then define $\theta_M \equiv \frac{w_M L_M}{P_M M}$ and $(1 - \theta_M) \equiv \frac{r K_M}{P_M M}$ as the shares of labor and capital in the production of the manufacturing good. Using these definitions, we rewrite equation above as follows:

$$\widehat{M} = \theta_M \widehat{L}_M + (1 - \theta_M) \widehat{K}_M. \tag{3.22}$$

Analogously:

$$\widehat{V} = \theta_V \widehat{L}_V + (1 - \theta_V) \widehat{K}_V. \tag{3.23}$$

Similarly, the shares of labor and capital from the total endowments used by the two sectors can be obtained by differentiating equations 3.3 and 3.4. Here the example is shown for the labor equation:

$$\frac{L_M}{\bar{L}} \frac{dL_M}{L_M} + \frac{L_V}{\bar{L}} \frac{dL_V}{L_V} + \frac{L_U}{\bar{L}} \frac{dL_U}{L_U} = 0, \tag{3.24}$$

Define $\lambda_{L_M} \equiv \frac{L_M}{\bar{L}}$, $\lambda_{L_V} \equiv \frac{L_V}{\bar{L}}$, and $\lambda_{L_U} \equiv \frac{L_U}{\bar{L}}$ as the shares of manufacturing labor, violent labor, and unemployed labor from the total amount of labor in the economy, and rewrite equation above using these shares as follows:

$$\lambda_{L_M} \widehat{L}_M + \lambda_{L_V} \widehat{L}_V + \lambda_{L_U} \widehat{L}_U = 0. \tag{3.25}$$

A similar linear equation for changes in capital is obtained by differentiating equation 3.4 and defining $\lambda_{K_M} \equiv \frac{K_M}{\bar{K}}$, and $\lambda_{K_V} \equiv \frac{K_V}{\bar{V}}$ as the shares of manufacturing and violence capital from the total amount of

capital in the economy:

$$\lambda_{K_M}\widehat{K}_M + \lambda_{K_V}\widehat{K}_V = 0. \tag{3.26}$$

The shares of labor sum to one as do the shares of capital:

$$\lambda_{L_M} + \lambda_{L_V} + \lambda_{L_U} = 1, \qquad \lambda_{K_M} + \lambda_{K_V} = 1. \tag{3.27}$$

Rearranging and solving for $\widehat{K}_M - \widehat{L}_M$ in equation 3.10, the behavioral equation for the manufacturing sector is obtained:

$$\widehat{K}_M - \widehat{L}_M = \sigma_M(\widehat{w}_M - \widehat{r}), \tag{3.28}$$

Similarly, the behavioral equation for the violence sector using the elasticity of production of equation 3.11 (σ_V) and solving for $\widehat{K}_V - \widehat{L}_V$ is:

$$\widehat{K}_V - \widehat{L}_V = \sigma_V(\widehat{w}_V - \widehat{r}). \tag{3.29}$$

Total differentiating equations 3.12 and 3.13, and using the factor shares θ_M, and θ_V, the following linear equations are found:

$$\widehat{M} + \widehat{P}_M = \theta_M(\widehat{L}_M + \widehat{w}_M) + (1-\theta_M)(\widehat{K}_M + \widehat{r}), \tag{3.30}$$

$$\widehat{V} + \widehat{P}_V = \theta_V(\widehat{L}_V + \widehat{w}_V) + (1-\theta_V)(\widehat{K}_V + \widehat{r}). \tag{3.31}$$

We define $\gamma = M^I/M^C$ as the imports share of manufacturing consumption, and $(1-\gamma)$ as the share of domestic production from manufacturing consumption, M/M^C. Then, we total differentiate equation 3.14 to get:

$$\widehat{M^C} = \gamma\widehat{M^I} + (1-\gamma)\widehat{M}. \tag{3.32}$$

The equation above describes how the consumption of manufacturing (M^C) changes when the production of manufacturing (M) and the manufacturing imports (M^I) change away from their initial shares. Because prices of manufacturing and violence are set fixed to world prices, the value of the total exports (V) would be equal to the value of the total imports (M^I), and the equation above can be rewritten as:

$$\widehat{M^C} = \gamma\widehat{V} + (1-\gamma)\widehat{M}. \tag{3.33}$$

The linear system is composed by 13 equations (3.16, 3.17, 3.18, 3.19, 3.22, 3.23, 3.25, 3.26, 3.28, 3.29, 3.30, 3.31 and 3.33) and 16 unknowns ($\widehat{L}_M$, $\widehat{L}_V$, $\widehat{L}_U$, $\widehat{L}_C$, $\widehat{K}_M$, $\widehat{K}_V$, $\widehat{w}_M$, $\widehat{w}^{\epsilon}_M$, $\widehat{w}_V$, $\widehat{w}^{\epsilon}_V$, $\widehat{r}$, $\widehat{M}$, $\widehat{V}$, $\widehat{M^C}$,

$\widehat{P}_M$ and $\widehat{P}_V$). Changes in the manufacturing wage (w_M) are determined exogenously. Additionally, as mentioned above, $\widehat{P}_M = \widehat{P}_V = 0$. With an exogenously determined manufacturing wage, and with the prices of manufacturing and illegal goods as numraire, the system of equations is composed by 13 linear equations and 13 unknowns, and can be solved by successive substitution.

3.3 Solution for factor prices and levels of employment

The calculation of the return of capital is obtained by first substituting equation 3.22 into equation 3.30 and solving for $\widehat{r}$. For obtaining $\widehat{w}_V$ this result is then used in equation 3.31 once equation 3.23 has been substituted there. The solutions for these first two variables are the following:

$$\widehat{r} = -\frac{\theta_M}{(1-\theta_M)}\widehat{w}_M, \tag{3.34}$$

$$\widehat{w}_V = \frac{(1-\theta_V)\theta_M}{\theta_V(1-\theta_M)}\widehat{w}_M. \tag{3.35}$$

The manufacturing product uses only labor and capital for its production. Given that the price of the manufacturing product is fixed, and firms must break even in competitive equilibrium, any increase in the manufacturing wage must be accompanied by a fall in the price of capital ($\widehat{r}$). A similar situation is observed in the violence sector. With a fixed price of the violence product and $\widehat{r}$ determined in the manufacturing sector, a reduction in the return to capital must increase the violence wage (or vice versa).

The changes in the exogenous prices ($\widehat{P}_M = \widehat{P}_V = 0$), the change in the exogenously determined $\widehat{w}_M$, and the calculation of $\widehat{r}$ and $\widehat{w}_V$ provide the solution for all the changes in the five prices in the economy. For the calculation of the levels of employment in the manufacturing and violence sectors, we reduce the system to a new system of equations with three equations and three unknowns. The first equation is obtained by substituting equations 3.16, 3.17 and 3.18 into equation 3.19, solving for $\widehat{L}_U$, and substituting it finally into equation 3.25 to get:

$$(\lambda_{L_M} + \lambda_{L_U})\widehat{L}_M + \left[\frac{\lambda_{L_V}\alpha + \lambda_{L_U}\eta}{\alpha}\right]\widehat{L}_V + \frac{\lambda_{L_U}\left[\theta_V(1-\theta_M) - \psi(1-\theta_V)\theta_M\right]}{\alpha\theta_V(1-\theta_M)}\widehat{w}_M = 0 \tag{3.36}$$

The second equation is obtained by solving for $\widehat{K}_M$ and $\widehat{K}_V$ in equations 3.28 and 3.29, respectively, and substituting these values into equation 3.26:

$$\lambda_{K_M}\widehat{L}_M + \lambda_{K_V}\widehat{L}_V + \frac{\lambda_{K_M}\sigma_M\theta_V + \lambda_{K_V}\sigma_V\theta_M}{\theta_V(1-\theta_M)}\widehat{w}_M = 0 \tag{3.37}$$

Finally the third equation is obtained by replacing $\widehat{K}_M$ and $\widehat{K}_V$ in equations 3.22 and 3.23, respectively, and these two into equation 3.33:

$$\widehat{M}^C = \gamma\widehat{L}_V + (1-\gamma)\widehat{L}_M + \frac{\gamma\sigma_V(1-\theta_V)\theta_M + (1-\gamma)\sigma_M(1-\theta_M)\theta_V}{\theta_V(1-\theta_M)}\widehat{w}_M \tag{3.38}$$

Equations 3.36, 3.37 and 3.38 constitute a linear system of three equations with three unknowns ($\widehat{L}_M$, $\widehat{L}_V$, and $\widehat{M}^C$). Substitutions techniques are used again to solve for $\widehat{L}_M$, $\widehat{L}_V$, which are the variables of interest to understand labor allocation:

$$\widehat{L}_M = \frac{\lambda_{L_U}\lambda_{K_V}\left[\theta_V(1-\theta_M) - \psi(1-\theta_V)\theta_M\right] - \left(\lambda_{L_V}\alpha + \lambda_{L_U}\eta\right)\left[\lambda_{K_M}\sigma_M\theta_V + \lambda_{K_V}\sigma_V\theta_M\right]}{\theta_V(1-\theta_M)\lambda^*}\widehat{w}_M, \tag{3.39}$$

$$\begin{aligned}\widehat{L}_V \quad &= \Big(\frac{\alpha(\lambda_{L_M}+\lambda_{L_U})(\lambda_{K_M}\sigma_M\theta_V+\lambda_{K_V}\sigma_V\theta_M)}{\lambda^*\theta_V(1-\theta_M)} \\ &\quad - \frac{\lambda_{L_U}[\theta_V(1-\theta_M)-\psi(1-\theta_V)\theta_M][\alpha\lambda_{K_V}(\lambda_{L_M}+\lambda_{L_U})+\lambda^*]}{(\lambda_{L_V}\alpha+\lambda_{L_U}\eta)\theta_V(1-\theta_M)\lambda^*}\Big)\widehat{w}_M,\end{aligned} \tag{3.40}$$

where $\lambda^* = (\lambda_{L_V}\alpha + \lambda_{L_U}\eta)\lambda_{K_M} - \alpha\lambda_{K_V}(\lambda_{L_M} + \lambda_{L_U})$.

3.4 Interpretation of the results

3.4.1 Relationship between λs, θs, α and the size of the manufacturing sector, β

To interpret the results, we first need to understand the relationship between λ_{K_M}, λ_{K_V}, λ_{L_M}, λ_{L_V} and λ_{L_U} with θ_M and θ_V. In the initial equilibrium, the total income produced by the manufacturing and the violence sector must be equal to their total expenses on labor and capital. Assuming that initial prices are equal to one, the equilibrium in the economy can be illustrated using table 3.1, where $\beta \equiv \frac{M}{M+V}$ is the size of the manufacturing sector, and $(1-\beta) \equiv \frac{V}{M+V}$ is the size of the violence sector. The manufacturing and violence sectors use labor and capital for their production, but labor can also be unemployed as shown by the third row of table 3.1.

The total income from manufacturing is equal to the proportion of manufacturing product in the economy, β, when the total income in the economy is normalized to one. From this amount, θ_M is spent on labor, and $(1-\theta_M)$ is spent on capital, as shown by the first and second columns of the "manufacturing" row. Analogously, a proportion of θ_V from the total violence in the economy $(1-\beta)$ is spent on labor, and a proportion of $(1-\theta_V)$ from the total violence product is spent on capital, as shown by the first and second columns of the "violence" row. Additionally, labor is not only used by the manufacturing and violence

sectors, but it can be also unemployed as shown in the third row of the table. Since α is the proportion of city labor that is unemployed, and $(1-\alpha)$ is the proportion of manufacturing labor from the total city labor force, we use cross multiplication to determine the amount of unemployed labor, which is shown in the first column of the "unemployed" row: if $\beta\theta_M$ of the total labor belongs to the manufacturing labor, and this amount corresponds to $(1-\alpha)$ of the city labor force, how much of the total labor in the economy would be unemployed, if a proportion α of the city labor force is unemployed? Defining the unemployed labor force as x, the first column of the third row is found by solving for x in the following equation:

$$\frac{\beta\theta_M}{x} = \frac{1-\alpha}{\alpha} \tag{3.41}$$

Considering the definitions for λ_{L_M}, λ_{L_V} and λ_{L_U} as the shares of labor, and λ_{K_M} and λ_{K_V} as the shares of capital, these expressions can be derived from the relationships shown in table 3.1. For example, λ_{L_M} is the proportion of manufacturing labor (first column from the "manufacturing" row), from the total labor in the economy (first column of the "Total Uses"). Similarly, λ_{K_V} is the proportion of capital used by the violence sector (second column of the "violence" row) from the total amount of capital in the economy (second column of the "Total Uses"). These relationships are expressed as follows:

$$\lambda_{L_M} = \frac{\beta\theta_M}{\beta\theta_M + (1-\beta)\theta_V + \beta\theta_M\alpha/(1-\alpha)} \tag{3.42}$$

$$\lambda_{L_V} = \frac{(1-\beta)\theta_V}{\beta\theta_M + (1-\beta)\theta_V + \beta\theta_M\alpha/(1-\alpha)} \tag{3.43}$$

$$\lambda_{L_U} = \frac{\beta\theta_M\alpha/(1-\alpha)}{\beta\theta_M + (1-\beta)\theta_V + \beta\theta_M\alpha/(1-\alpha)} \tag{3.44}$$

$$\lambda_{K_M} = \frac{\beta(1-\theta_M)}{\beta(1-\theta_M) + (1-\beta)(1-\theta_V)} \tag{3.45}$$

$$\lambda_{K_V} = \frac{(1-\beta)(1-\theta_V)}{\beta(1-\theta_M) + (1-\beta)(1-\theta_V)} \tag{3.46}$$

Before plugging these definitions into the solutions for $\widehat{r}$, $\widehat{w}_V$, $\widehat{L}_M$ and $\widehat{L}_V$, section 3.4.2 simplifies these expressions by assuming that the share of labor in manufacturing is the same as the share of labor in the violence sector, and that the two sectors have the same elasticity of substitution.

3.4.2 Special case: Same factor shares for manufacturing and violence ($\theta_M = \theta_V$) and same elasticity of substitution ($\sigma_M = \sigma_V$)

By assuming that the share of labor in manufacturing is the same as the share of labor in the violence sector, and that the two sectors have the same elasticity of substitution, the expressions in equations 3.42 to 3.46 can be simplified as follows:

$$\lambda_{L_M} = \frac{\beta(1-\alpha)}{\beta + (1-\beta)(1-\alpha)}, \tag{3.47}$$

$$\lambda_{L_V} = \frac{(1-\beta)(1-\alpha)}{\beta + (1-\beta)(1-\alpha)}, \tag{3.48}$$

$$\lambda_{L_U} = \frac{\alpha\beta}{\beta + (1-\beta)(1-\alpha)}, \tag{3.49}$$

$$\lambda_{K_M} = \beta, \tag{3.50}$$

$$\lambda_{K_V} = (1-\beta). \tag{3.51}$$

These relationships are then substituted into the solutions for the changes in the violence wage, the return to capital, the manufacturing labor and the violence labor, facilitating the interpretation of the results. Using θ as the share of labor in both sectors and σ as the elasticity of substitution in both sectors, the simplified equations for $\widehat{w}_V$, $\widehat{r}$, $\widehat{L}_M$ and $\widehat{L}_V$ are the following:

$$\widehat{r} = -\frac{\theta}{(1-\theta)}\widehat{w}_M, \tag{3.52}$$

$$\widehat{w}_V = \widehat{w}_M, \tag{3.53}$$

$$\widehat{L}_M = \frac{\sigma\left[(1-\alpha)(1-\beta) + \beta\eta\right]}{\beta(1-\theta)\left[\alpha(1-\beta) - \beta\eta\right]}\widehat{w}_M - \frac{(1-\beta)(1-\psi)}{\alpha(1-\beta) - \beta\eta}\widehat{w}_M, \tag{3.54}$$

$$\widehat{L}_V = \frac{\beta(1-\psi)(1-\theta) - \sigma}{(1-\theta)\left[\alpha(1-\beta) - \beta\eta\right]}\widehat{w}_M. \tag{3.55}$$

We then use equations 3.54 and 3.55 to find a simplified solution for the change in the unemployed labor:

$$\widehat{L}_U = \frac{\sigma(1-\alpha)}{\alpha\beta(1-\theta)}\widehat{w}_M. \tag{3.56}$$

Since the firms in the manufacturing industry must break even, and the price of output is fixed as numeraire, the government's increase in the minimum wage paid to labor necessitates a fall in the return to capital of a particular size. Because the return of capital is the same for the manufacturing and the violence sector, its reduction increases the wage in the violence sector. With the same factor shares in each sector,

the increase of the violence wage is the same as the increase in the manufacturing wage. Given that wages in both sectors rise, the changes in the violence and manufacturing labor demands are ambiguous and depend on the initial conditions of the economy.

An increase in the manufacturing wage always increases unemployment in the cities, either because workers are laid off from their manufacturing jobs, or because the higher wage attracts workers from the other sector. This increase is smaller with high levels of initial unemployment (α). The incentives to migrate to the city caused by an increase in the manufacturing wage are smaller when the initial unemployment is high. Then, the increases in unemployed labor, caused by the increase in the manufacturing wage are not as large as when the initial unemployment is low.

A similar situation is observed with the changes in the manufacturing labor due to an increase in the manufacturing wage. When the initial unemployment is high, then the increase in the minimum manufacturing wage results in less migration from the violence sector to the cities. As a result, changes in the manufacturing labor are lower when starting with high levels of initial unemployment. On the contrary, the violence labor becomes more attractive with high levels of initial unemployment: not only does the violence wage increase in tandem with the increase in the manufacturing wage, but the labor in the violence sector is also fully employed.

The parameter ψ tells us the size of the initial gap is between the initial monetary violence wage (w_V) and the initial expected violence wage (w_V^ϵ). A larger gap is associated with greater levels of initial violence, because workers receive greater disutility for being employed in an illegal activity. The parameter η is the elasticity of disutility with respect to labor in the violence sector. It can be inelastic (less than one) or elastic (greater than one), depending on how much the utility is affected by changes in the violence labor. While ψ is related to the initial *levels* of the monetary and expected violence wage, the parameter η is related to the size of the *changes* in the violence labor.

An increase in the manufacturing wage produces larger changes in the violence labor with higher levels of ψ and η. With an increase in the manufacturing wage, the incentives to migrate from the violence sector are greater with high levels of initial violence. The disutility generated by working for something illicit makes the manufacturing sector more attractive to violence workers than the violence sector. This situation is observed by analyzing equations 3.54 and 3.55. The ψ parameter is greater than one because the effective violence wage is lower than the monetary wage with the existence of violence. Then, the term $(1 - \psi)$ is negative. With an increase in the manufacturing wage, the parameter ψ affects positively the manufacturing labor and negatively the violence labor, as observed in equations 3.54 and 3.55, respectively. When the difference between the initial values of w_V and w_V^ϵ is large, an increase in the manufacturing wage increases

the labor in the manufacturing sector and reduces the labor in the violence sector.

Equation 3.54 also shows that the changes produced by an increase in the manufacturing wage in the manufacturing labor are greater when elasticity of disutility, η, is high. With an increase in the manufacturing wage, greater values of η imply a larger numerator of the first term in equation 3.54, increasing the labor in the manufacturing sector. However, the parameter η also enters into the denominator of the expression of $\widehat{L}_M$ making the sign of equation 3.54 ambiguous. Manufacturing labor increases when the expression $(\alpha(1-\beta)-\beta\eta)$ is positive, and decreases when this expression is negative. The opposite situation is observed in equation 3.55: with an increase in the manufacturing wage, changes in the violence labor are positive when $(\alpha(1-\beta)-\beta\eta)$ is negative, and vice versa.

Let us analyze the plausible values of expression $(\alpha(1-\beta)-\beta\eta)$. When the initial size of the manufacturing sector is the same as the initial size in the violence sector $(\beta=(1-\beta))$, whether the sign of $\widehat{L}_M$ is positive or negative, depends on the values of α and η. The manufacturing labor increases when $\alpha>\eta$, and decreases when $\eta>\alpha$. Although these terms are comparable arithmetically, they are not comparable economically. While α is the initial proportion of unemployed labor in the cities, η is a disutility elasticity. Thus, assuming that $\alpha>\eta$ does not mean that the initial level of unemployment is greater than the initial level of violence, or vice versa.

The changes in the manufacturing labor also depend on the initial size of the manufacturing sector. When the manufacturing sector is bigger than the violence sector, and most of the labor is employed there, labor in the violence sector is more valuable because it is relatively more scarce. Therefore, when $\alpha=\eta$, and $\beta>1-\beta$ an increase in the manufacturing wage, and consequently in the violence wage, leads to increases in violence labor and reductions in manufacturing labor.

These different scenarios are all plausible, and as we show in section 3.5, both distortions -unemployment and violence- have similar effects in all scenarios. The effects on manufacturing and unemployed labor caused by increasing the manufacturing wage are smaller with high initial levels of unemployment and are intensified in the manufacturing labor with high initial levels of violence. These effects are reversed in the violence sector: the consequences of increasing the manufacturing wage are intensified when the initial level of unemployment is high, and the effects are weaker with high levels of initial violence. The next section shows the results of a sensitivity analysis with different values for the parameters, and the consequences of increasing the manufacturing wage in terms of unemployment and violence.

3.5 Sensitivity analysis of the different scenarios

From equations 3.54 and 3.55 analyzed in section 3.4.2, we have shown that changes in the manufacturing and the violence labor resulting from an increase in the manufacturing wage depend on the magnitudes of the initial level of unemployment (α), the elasticity of disutility with respect to labor in the violence sector (η), and the size of the manufacturing sector in the economy (β). The structure of the model, particularly of the production functions (constant returns to scale and perfect competition) implies that $\widehat{w}_M = \widehat{w}_V$, so both wages increase the same. Then, it is ambiguous whether L_M or L_V might increase or decrease. When $\alpha > \eta$ and the size of the manufacturing sector is equal to the size of the violence sector, an increase in the manufacturing wage increases the labor in the manufacturing sector and reduces the labor in the violence sector. On the contrary, when $\alpha < \eta$ an increase in the manufacturing wage increases the labor in the violence sector and reduces the labor in the manufacturing sector.

Figure 3.1 shows changes in labor of each sector (manufacturing, violence and unemployment) for an increase in the manufacturing wage, given different levels of η. In the simulation, 20% of the city labor force is initially unemployed ($\alpha = 0.2$), and the factor shares for the violence and the manufacturing sectors -as well as the elasticity of substitution- are 0.5. Parameter ψ is also fixed to 1.5, meaning that the initial expected violence wage is 33% lower than the initial monetary violence wage. When $\eta < 0.2$, an increase in that wage increases labor in the manufacturing sector, and reduces labor in the violence sector, as shown in the left side of figure 3.1. This increase is greater with higher values of η, up to a point. Workers in the violence sector are attracted to the cities because of the increase in the manufacturing wage. With a high level of violence in the violence sector, the incentives to migrate to the cities are stronger, not only because of the increase in the manufacturing wage but also because of the disutility resulting from working in the violence sector. Unemployed labor increases with a rise in the manufacturing wage; this increase is the same for different values of the elasticity of disutility, η.

The right side of figure 3.1 shows a situation in which the parameter η is greater than the parameter α. The level of initial city unemployment is still 20%, but now the elasticity of disutility with respect to labor in the violence sector is higher. When the manufacturing sector is the same size as the violence sector, and $\eta > \alpha$, an increase in the manufacturing wage decreases the manufacturing labor and increases the violence labor. In this case, workers are moving from cities to the violence sector, attracted by the increase in the violence wage. Although the sign of the changes in labor are opposite to the case when $\eta < \alpha$, with high initial levels of violence an increase of the manufacturing wage reduces less (or increases more) the manufacturing labor, while increasing less (or reducing more) the violence labor.

In figure 3.2 we show how increasing the manufacturing wage affects the labor variables, with different

initial sizes of the manufacturing sector (more or less than 50% of the total economy). In every case, we fix the initial level of unemployment to 20%, as well as the elasticity of disutility with respect to the violence labor ($\alpha = \eta = 0.2$).

Under the conditions described above, an increase in the wage in both sectors reduces the labor in the violence sector, but only when the violence sector is larger than the manufacturing sector in the initial equilibrium ($\beta < 0.5$). When the manufacturing sector is larger than the violence sector in the initial equilibrium ($\beta > 0.5$), an increase in the wage reduces labor in the manufacturing sector and increases labor in the violence sector. The unemployed labor always increases with a rise in the manufacturing wage, either because of the workers migrating to the cities from the violence sector, or because workers are laid off from the manufacturing sector. However, the increase in the unemployed labor is lower when the initial size of manufacturing labor is larger than the size of the violence sector.

The interpretation of these results is related to the relative size of the sectors and their maximum capacity. Wages in both sectors increase in the same proportion, and both sectors have distortions that affect the allocation of workers. When $\beta > 0.5$, the increase in the manufacturing wage makes labor in the violence sector become scarce and raises the wage there. Thus, given the increase in both wages, workers will move to the violence sector where labor is scarce relative to labor in the manufacturing sector. In the opposite situation, when the initial size of the violence sector is greater than the size of the manufacturing labor, the scarcity of labor in the cities attracts workers from the violence sector, increasing not only the labor in the manufacturing sector but also the unemployed labor.

Finally, let us analyze the results under different initial levels of city unemployment. In this case, we assume that the size of both sectors is the same ($\beta = 0.5$), and we fix the elasticity of disutility with respect to labor to 0.5 ($\eta = 0.5$). Again, the shock analyzed is an increase in the manufacturing wage. The changes in the manufacturing, violence and unemployed labor are shown in Figure 3.3.

As expected, an increase in the manufacturing wage increases the unemployed labor, but the changes are smaller when the initial equilibrium has high unemployment. The changes in the manufacturing and the violence labor, with an increase of the manufacturing wage, depend on the initial levels of violence and unemployment, and the initial size of the manufacturing sector. Workers laid off from the manufacturing sector due to an increase in the manufacturing wage either become unemployed or migrate to the violence sector. As a result, the unemployed labor and the violence labor increase. However, the situation is reversed with higher levels of initial unemployment and lower levels of elasticity of disutility, η. In this case, with an increase in the manufacturing wage, we still observe a negative relationship between the initial level of unemployment and the changes in the manufacturing and the unemployed labor, but the changes in these

variables are positive, suggesting that workers from the violence sector migrate to the cities after being laid off due to the increase in the violence wage. The migration from the violence sector to the cities is lower when the initial level of unemployment is extremely high and the changes in the labor variables are reduced almost to zero.

In the three scenarios analyzed, where different values are assigned for the different parameters of the model, the effect of the initial conditions on the economy is the same for the labor variables. Disregarding the sign of the variable change, a high level of unemployment always reduces the incentives to migrate to cities, even with an increase in the minimum wage. Therefore, the changes in the manufacturing labor and the unemployed labor are less positive (or more negative) when the initial unemployment is high.

On the other hand, the elasticity of disutility with respect to violence labor -a parameter that measures the effect of the violence labor in the utility- increases the migration incentives to the cities, even with high levels of initial unemployment. With greater values of this elasticity (η), the changes in the violence labor, due to an increase in the manufacturing wage, are more negative (or less positive), suggesting that even with an increase in the violence wage, workers employed in the violence sector also consider the disutility caused by fear and guilt, and decide to move to the cities, despite their suboptimal condition.

3.6 Conclusions and policy implications

This paper describes a general equilibrium model of an economy with two distortions: unemployment and violence. Unemployment affects the effective wage perceived by the manufacturing workers because it reduces the probability of employment in the cities. On the other hand, violence directly affects the utility of individuals. By working in the violence sector, workers receive a disutilty related to the fear and guilt of doing something illegal. Considering these two distortions, the model analyzes the workers' allocation decision between the manufacturing and the violence sectors.

Several conclusions can be drawn from this analysis, but the most important is that workers' allocation decisions cannot be understood simply by analyzing the wage differentials between regions. With an increase in the manufacturing wage, the wage in the violence sector increases also. Our results suggest that changes in the labor supplies in each sector depend on the initial conditions of the economy. A high initial level of unemployment makes cities less attractive, even with a rise in the manufacturing wage. Manufacturing labor increases are lower if initial unemployment is high; and manufacturing labor reductions are greater with high initial unemployment. A similar situation is observed with the violence sector and the initial level of violence. If an increase in the wage increases the violence labor, this increase is lower with high initial

levels of violence. Similarly, if the increase in the wage reduces the violence labor, this reduction is greater with high levels of initial violence.

Policy makers thus face a tradeoff when deciding to increase the manufacturing wage. In some cases, depending on the initial conditions, such a policy will reduce the size of the violence sector, which is beneficial for the economy; however, it will also increase unemployed labor by attracting more workers to the cities. In other cases where both the unemployed and the violence labor increase, the policy would not be effective for reducing either of the distortions. An effective solution to reduce both unemployment and violence would be to reduce the manufacturing sector's minimum wage, and, depending on the initial conditions of the economy, both the unemployed and the violence labor could be reduced, while the manufacturing sector grows and employs more workers.

In this paper, the policy analyzed is an increase in the manufacturing sector's minimum wage, policy that is imposed by the government, but implemented by the manufacturing firms. A more interesting policy could be analyzed if the government is included in the model. For example, instead of imposing an increase in the manufacturing wage, the government could provide subsidies to the manufacturing firms to increase the wage. In this case, the subsidies should be financed by an increase in taxes only to the manufacturing sector, given that the other sector in the economy is illegal, then it would not pay taxes. The model can also be replicated by analyzing changes in the export price of the violence sector's exports, or by "legalizing" the sector and defining a tax structure for the manufacturing and the violence sector's firms.

This model can be tested by using real data and by relaxing some of the assumptions. For example, the unemployment could be understood as a national phenomenon instead of just an urban distortion. The model could include also a third sector called Agriculture to observe rural allocation decisions within the same region. Finally, the linkage between the manufacturing sector and the violence sector is determined not only by the allocation of workers, but also by the external sector: the value of manufacturing imports is equal to the value of the violence sector's drug exports. In reality, the connection between manufacturing and illegal drugs in not that tangible. In Colombia, some of the proceeds received by the illegal exports are reinvested in the economy through money laundering. In other words, some manufacturing imports are bought with illegal money and sold in the national economy. However, assuming that all the manufacturing imports are bought with illegal drug money is an overstatement. Finally, it is worth to recognize an important limitation of the analysis. The model is unfeasible when the size of the manufacturing sector is equal to the size of the violence sector, and the parameters that define initial unemployment and initial violence are the same. In this case the changes in the labor supplies go to infinitive and we are not able to provide an explanation of the results. Future work will investigate this issue further.

Table 3.1: The fraction of total income that is attributable to each factor in each sector.

	Labor column 1	**Capital** column 2	**Total Income** column 3
Manufacturing	$\beta\theta_M$	$\beta(1-\theta_M)$	β
Violence	$(1-\beta)\theta_V$	$(1-\beta)(1-\theta_V)$	$(1-\beta)$
Unemployment	$\beta\theta_M\alpha/(1-\alpha)$	0	0
Total Uses	$\beta\theta_M + (1-\beta)\theta_V$ $+\beta\theta_M\alpha/(1-\alpha)$	$\beta(1-\theta_M) + (1-\beta)(1-\theta_V)$	1

For the total national income of 1.0, each cell shows the fraction of that income that is generated by the factor of production of that column, employed in the sector of that row. Since β is the share of income in manufacturing and θ_M is the share of manufacturing going to labor, the first cell shows that $\beta\theta_M$ is attributable to labor in manufacturing. The third row of the first column is calculated by solving the following problem: if $\beta\theta_M$ is the amount of labor used in the manufacturing sector, and this amount corresponds to a proportion of $(1-\alpha)$ of the city labor, how much of the total labor is unemployed if the unemployment corresponds to a proportion of α of the total city labor? Finally, the last row is just the sum of the columns.

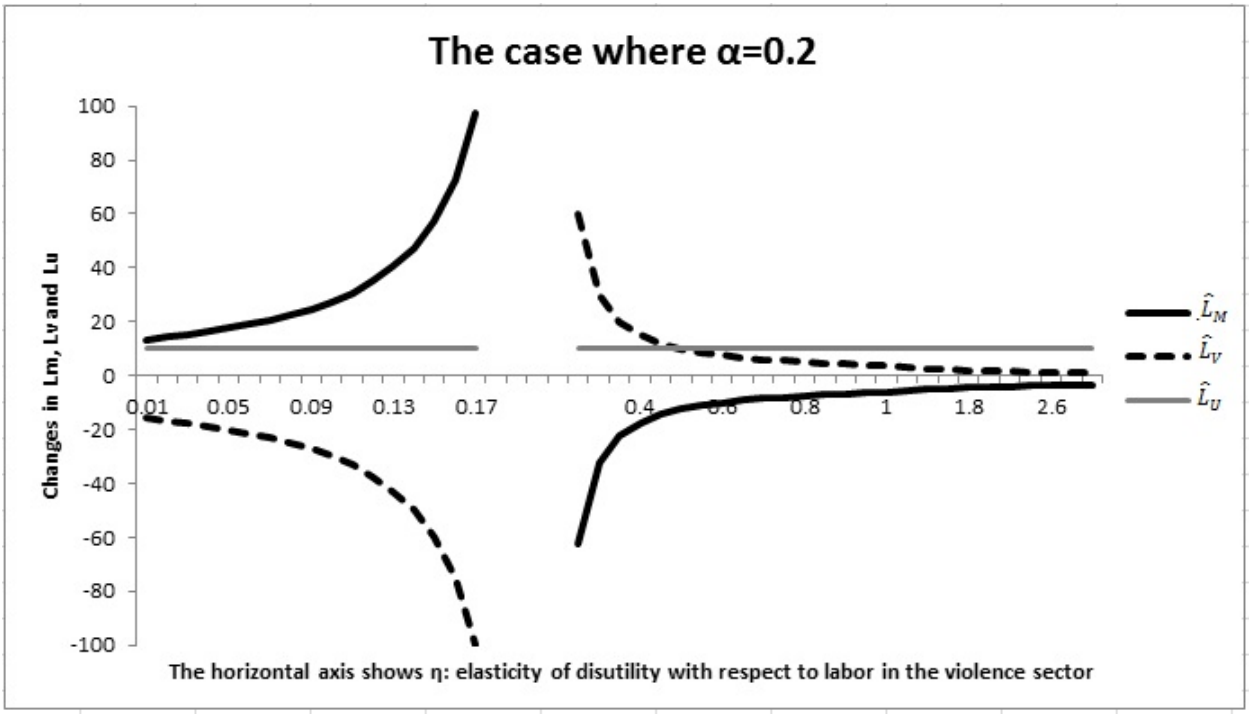

Figure 3.1: Changes in L_M, L_V and L_U from a change in the manufacturing wage for different initial levels of η on the horizontal axis (elasticity of disutility). Other parameters: $\alpha = 0.2$, $\theta = 0.6$, $\sigma = 0.5$, $\beta = 0.5$.

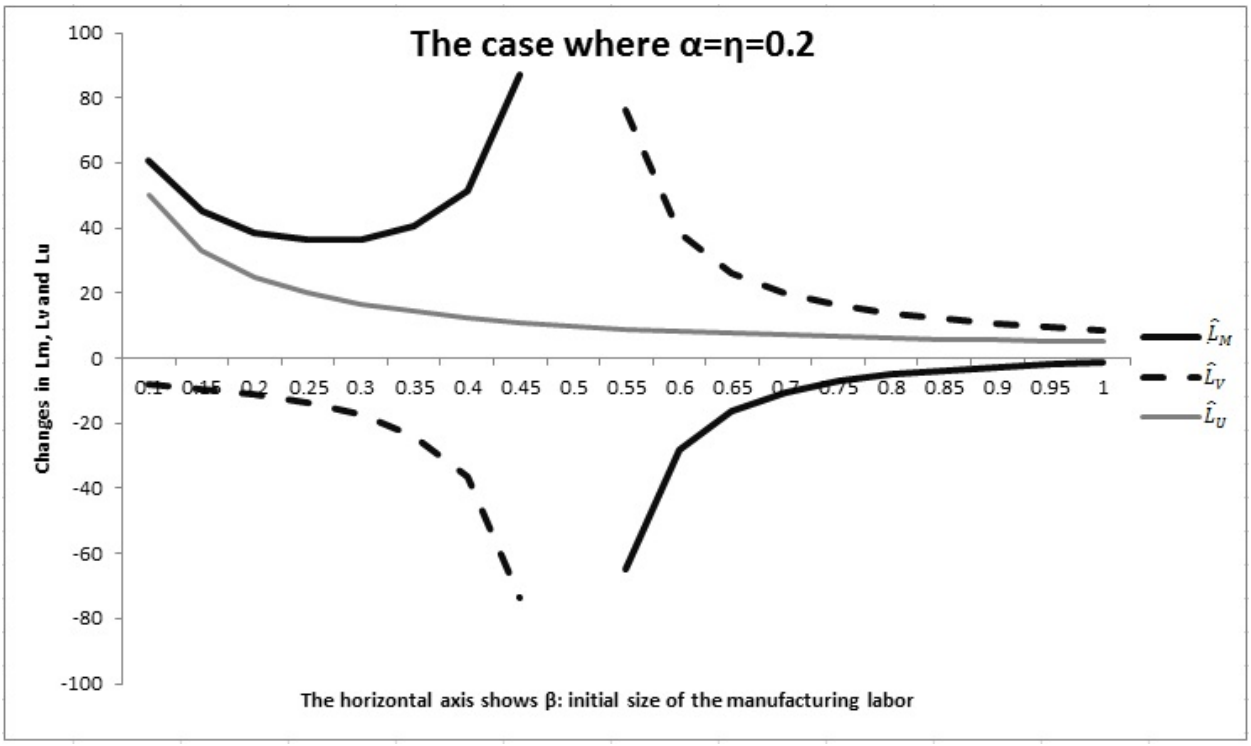

Figure 3.2: Changes in L_M, L_V and L_U from a change in the manufacturing wage for different initial levels of β on the horizontal axis (size of the manufacturing sector). Other parameters: $\alpha = 0.2$, $\eta = 0.2$, $\theta = 0.6$, $\sigma = 0.5$.

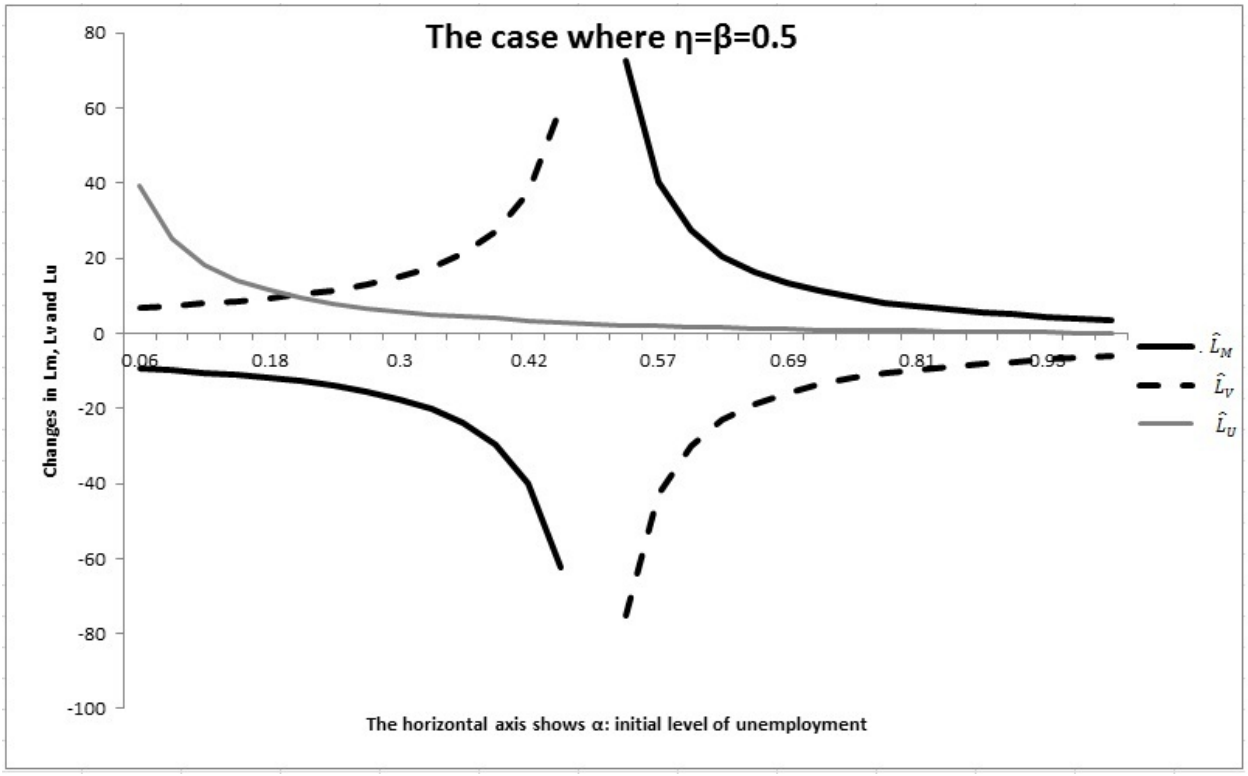

Figure 3.3: Changes in L_M, L_V and L_U from a change in the manufacturing wage for different initial levels of α on the horizontal axis (initial unemployment in the cities). Other parameters: $\beta = 0.5$, $\eta = 0.5$, $\theta = 0.6$, $\sigma = 0.5$.

Chapter 4

What are the effects of having drugs be illegal? A CGE microsimulation model for Colombia

4.1 Introduction

Cocaine demand has increased worldwide since the 1970s, primarily in Europe and the U.S. According to a 2007 report by the United Nations Office of Drugs and Crime (UNODC), 5.7 million people in the U.S. have used cocaine at least once. Worldwide, between 15 and 20 million people are considered cocaine users. The main producers of cocaine are located in the Andean region of South America, including Colombia, Peru and Bolivia, with Colombia being the main producing country. In Colombia, the production and trafficking of cocaine and other drugs such as heroin are strongly related to the on-going civil war, deeply affecting the socioeconomic welfare of the population. Although illegal drugs did not cause the war, they continue to play an important role in perpetuating it by providing income for the purchase of weapons and other materials (Angrist and Kugler, 2008).

This paper attempts to measure the effects of a worldwide legalization of drugs on household economic welfare in Colombia, based on different assumptions about the termination of the armed conflict. The idea behind the shock is to create a counterfactual to understand the effects of having drugs illegal, instead of simulating a very unlikely scenario. Drug legalization could significantly contribute to ending the civil war by greatly reducing the main source of rebel funding. This scenario is compared with one in which the armed conflict continues after legalization. Such legalization would have to be a worldwide decision in order to be beneficial to the Colombian economy. Otherwise, the most likely possible outcome of Colombian drug legalization would be the movement of the black market to a neighboring country, a situation already observed after the imposition of strict anti-drug policies in Peru.

Most of the existing literature measuring the economic impact of illegal drugs in Colombia uses an econometric or partial equilibrium analysis. For example, Gibson and Godoy (1993) use a general equilibrium approach to measure the effects of a rise in illegal drug price on the Bolivian economy. However, regarding Colombia, no other study has used a computable general equilibrium (CGE) model to measure legalization impacts. Steiner (1998) uses production data to estimate the net income derived by the Colombian drug

trade, while Dion and Russler (2008) use an econometric approach to study the relationship between coca cultivation, displacement, poverty and government presence in coca-growing regions. Ibanez and Velez (2008) calculate the welfare losses of the civil conflict and forced migration, but do not consider drug-legalization scenarios. Mejia and Restrepo (2008) build a game theory model to evaluate the economic consequences of the war on drugs and the "Plan Colombia", a US$4.5 billion U.S. initiative from 2000 to 2005 to end the armed conflict and eliminate drug trafficking (Veillette, 2006). Angrist and Kugler (2008) measure the effects of prohibition in Colombia using the aerial bridge interdiction between Peru and Colombia as a quasi-experiment, while Becker et al. (2006) compare the cost of prohibition with an optimal tax on consumption to reduce the demand for drugs.

In contrast to the previous literature that used only partial equilibrium analyses, this work contributes to the field through the development of a CGE model with microsimulations to simulate the microeconomic effects of drug legalization, once all the sectors of the economy have been affected. The production side of the economy is disaggregated such that the main sectors affected by the legalization can be analyzed, and the demand side is disaggregated by location of households, urban and rural, and by income deciles in each of these locations. Two econometric models are considered. The first is a labor participation model estimating changes in the labor markets and migration flows. The second is an Almost Ideal Demand System with censored data used to estimate the households' demand, and to calculate welfare measures once the CGE model has been calibrated. The possible effects of drug legalization on the country are replicated by imposing several shocks to the economy.[1]

Six scenarios are analyzed with different assumptions about the legalization of drugs. In the first four, the armed conflict ends with legalization and the government spends less money on security expenditures. The scenarios vary depending on the movement of the export price of drugs, and on the reinvestment of the security expenditures in other productive sectors such as health, education and transportation. The last two scenarios assume that the armed conflict continues, so the government keeps investing in security expenditures, but that the export price of drugs changes. In terms of economic welfare, the best scenarios are when the armed conflict continues and the households benefit from the redirection of the "economy of war" expenditures. These gains are not equally distributed among the population: the poorest households benefit more than the richest households and rural areas receive greater gains than urban areas. When legalization ends the armed conflict, welfare losses are observed in the highest income deciles if the government does not reinvest the security expenditures in other productive sectors. If the government makes those reinvestments,

[1] Due to the lack of information about what would happen in a producer economy if drugs were to be legalized, these shocks are based on assumptions made by the author given the available information. A sensitivity analysis of each of the assumptions is conducted to analyze how different magnitudes in the changes of the parameters affect the results of the model.

all households improve their economic welfare.

The paper is divided as follows. The first section presents a description of the role of illegal drugs in the Colombian armed conflict and the subsequent socioeconomic consequences. Then, section 4.3 presents the microeconomic models and their interaction with the CGE model. The CGE model and the shocks used to simulate the four scenarios of legalization are explained in section 4.4, and results are shown in section 4.5. Finally, section 4.6 provides some concluding remarks and policy implications of the legalization of drugs.

4.2 Role of the illegal drugs in Colombia

The civil war in Colombia began with the period known as *La Violencia* (1948-1957) during which the two political parties engaged in a war for power. Following the Cuban revolution, several communist guerrilla units were formed as a response to the political exclusion the country was facing. Illegal drugs began playing an important role in the civil war in the mid-1960s when the domestic demand for marijuana created an economic opportunity. Marijuana production intensified when the U.S. implemented eradication programs in Mexico using herbicides and production moved to Colombia to supply the international demand (Thoumi, 2002).

Cocaine exports began in the mid-1970s. The exorbitant profits allowed traffickers to establish stable routes and to connect the business with the main producers of coca leaves in Peru and Bolivia. The creation of drug cartels in Colombia further expanded the business. Narcotraffickers used the "aerial bridge" to transport coca paste from Peru to Colombia in order to be processed and trafficked to demander countries (Mejia and Posada, 2007). In 1996, the Peruvian and U.S. governments authorized interdiction programs to block the aerial bridge between the two countries. The flights between Peru and Colombia using the air bridge were indeed reduced by 50%; however, cocaine production did not decrease, and a shift in the organization took place, increasing prices in Colombia and stimulating the planting of coca crops in the country (Angrist and Kugler, 2008).

The coca crops were grown in areas of the country with very limited state presence. Given the new sources of revenue, the guerrillas exploited the opportunity of gaining additional funding by "taxing" the peasants who grew coca. This tax and extortion system imposed by the guerrillas, and later by paramilitary groups, is the main link between the civil conflict and the illegal drug markets (Angrist and Kugler, 2008). According to Echeverry (2004), the guerrillas income between 1990 and 1996 was between US$370-680 million: 41% of this was estimated to come from the illegal drug trade, 20% from extortion, and 39% from corruption and investment. If the peasants refuse to pay the "drug taxes" to the guerrillas and paramilitaries, they are

kidnapped, threatened or killed. For most of them, the only remaining option is to migrate to urban centers and become part of the internally displaced population (IDP).

According to the U.S. Committee for Refugees, Colombia ranks among the top ten countries worldwide in displaced population (see Engel and Ibanez, 2007; and Lozano-Gracia et al., 2010). Focusing on the capital city, Bogot, of the 6.5 million population counted in the 2005 Census (DANE, 2010), 2.5 million were internal immigrants. The internal displaced population has been estimated to be around 40,000 per year according to official statistics produced by CODHES (2010).

The regions with the highest population displacement coincide with the highest production of coca. These are located in the south and southeast of the country and in some areas in the West. This relationship between displacement and the existence of illegal crops is well-documented by the literature. Dion and Russler (2008) find a relationship between state presence, aerial eradication and displacement, and between displacement and coca cultivation. Ibanez and Velez (2008) find a positive relationship between the probability of displacement and the presence of paramilitary and guerrilla groups, and a negative relationship between the probability of displacement and the presence of military and police forces.

The internally displaced population is not the only socioeconomic consequence of the conflict. Tax revenue not received because of the illegality of the market represents a significant loss for the government. Echeverry (2004) estimates the net earnings of the drug business to be US$1.9 billion, corresponding to 2.3% of the Colombian GDP, including costs of inputs, interdiction and money laundering. Following these calculations, not only does the government not receive tax revenue, but the earnings are not being reinvested in the country or redistributed among the population, especially among the rural households directly associated with the production process.

The U.S. government has spent significant resources in Colombia trying to reduce the production and trafficking of narcotics through the Plan Colombia. Even with the advances in illegal crop eradication, drug consumption in the U.S. has not decreased, creating a question about the wisdom of the strategies to eliminate the production of raw materials rather than attacking the commercialization of the final product.

Several authors have argued against illegal drug prohibition based on eradication policies. Attacking the supply does not decrease consumption because the illegal drug demand is price inelastic (Echeverry, 2004). Mejia and Posada (2007) argue that consumer countries should spend more money trying to reduce the demand for illegal drugs within their borders, or legalize this use instead of investing in implementation of anti-drug policies in producer countries. In the following sections, the Colombian economy under prohibition is compared with the same economy under legalization to evaluate household welfare impacts of the legalization of drugs.

4.3 Description of the microeconometric models

The literature describes several methods for introducing micro analysis into macroeconomic models. The simplest is to introduce heterogeneous representative households in the CGE models (see Lofgren et al., 2003; and Dervis et al., 1982). This approach has been criticized because it is not possible to model microeconomic behavior within groups with just one representative household per group. In this case, all households must have the same budget shares because the demand is not being estimated econometrically (Bourguignon et al., 2008). To introduce household level data in macro models, three approaches have been suggested by the literature: top-down (TD) modeling, bottom-up (BU) modeling, and feedback loops from bottom to top (see Bourguignon et al., 2008 for a review).

In this paper, the drug legalization shock implemented at the macro level produces two main effects at the micro level: (1) it affects migration flows between rural and urban areas, and between different urban labor markets, and (2) it affects households' economic welfare by changing prices and household expenditures. In order to account for these micro effects, two microeconometric models are introduced in the analysis. The first is a model of labor participation, which is linked to the CGE model using the feedback loops approach. The second is a model of demand using the Almost Ideal Demand System (AIDS). The AIDS "feeds" the CGE model before the introduction of the shock (BU approach), and the results of the CGE model are used as inputs in the AIDS model to calculate welfare effects of the macro shock (TD approach). Figure 4.1 shows the dynamics and the interaction between the three models.

4.3.1 The labor participation model

Both the labor participation model and the AIDS model use the Integrated Household Survey of Income and Expenses (GEIH) of 2007 for Colombia. The Survey was conducted in both rural and urban areas and it collects information about the demographics, income, expenses and labor characteristics of 64,119 different households. Most of the information is available at the household level and disaggregated information is also available for the household head. The labor participation model uses labor and demographic characteristics of the household heads, assuming that the behavior of other household members is the same.

As mentioned above, the labor participation model is used to estimate the labor supplies for use in the CGE model, and then the wage changes from the CGE model are used to calculate changes in labor supplies and migration flows across different labor markets. This model follows the methodology used by Magnac (1991), Cogneau and Robilliard (2006) and Savard (2003) for segmented labor markets. In this specific case, the disaggregation is done not only in urban areas, but also includes rural areas. Three different labor markets and unemployment are considered: rural labor, informal urban labor and formal urban labor.

Table 4.2 shows a summary of the statistics of the labor market at the initial equilibrium: 45.80% of the total households belong to the rural sector while 54.19% belong to the urban sectors. From the urban households, 28.74% are unemployed, 30.95% belong to the informal sector, and 40.37% to the formal sector. Rural workers have the lowest level of education, and most of the unemployed are women.

The highest wages are earned by the formal sector, followed by rural workers and informal workers. Notice that the informal wages are lower than the rural wages, suggesting an incentive to migrate from the urban informal market to the rural areas. However, in the case of Colombia, the armed conflict in the countryside makes the rural areas less attractive, affecting the migration decisions of urban workers. To determine how much informal workers would earn in rural areas, or rural workers in the urban labor markets, a microeconomic model is needed to control for demographic and social characteristics of households.

Potential wages for each of the labor markets and reservation wages for the unemployed are calculated using the Heckman two-step method with a biprobit estimation in the first step. The first step calculates the probability of a worker living in rural or in urban areas, and the probability of being employed in any of the intra-labor markets. The second step uses the Mills ratio of the first step in an ordinary least squares estimation to estimate the potential wages of each of the workers in each sector given their demographic and social characteristics. A detailed description of the model, and the estimates of the regressions can be found in Appendix A.

Once the potential wages are calculated, the migration flows are defined by this scheme, following Cogneau and Robilliard (2006) and Savard (2003):

1. The worker i chooses the rural sector if $w_i^R > w_i^E$.
2. The worker i chooses to be unemployed if $w_i^0 > w_i^R$, $w_i^0 > w_i^I$, and $w_i^0 > w_i^F - cost_f$.
3. The worker i chooses the informal sector if $w_i^I > w_i^R$, $w_i^I > w_i^0$, and $w_i^I > w_i^F - cost_f$.
4. The worker i chooses the formal sector if $w_i^F - cost_f > w_i^R$, $w_i^F - cost_f > w_i^0$, and $w_i^F - cost_f > w_i^I$,

where w_i^R is the rural potential wage of worker i; w_i^0 is the urban reservation wage of worker i; w_i^I is the informal potential wage of worker i; and $w_i^F - cost_f$ is the formal potential wage of worker i minus a cost of entry to the formal market, which is also estimated econometrically. The definition of the expected wage (w_i^E) which enters into the migration decision of rural workers, follows Harris and Todaro (1970): it is equal to the product between urban wages (both informal and formal wages) and the probability of getting a job in the urban sector (in the informal and formal markets). Unemployment in both urban and rural areas is considered in the migration decision.[2]

[2]Following official statistics and estimates by the author, an unemployment rate of 10% is considered in both areas.

Simply by observing the wage differentials, we can see that most of the unemployed and informal workers are better off in the rural areas than in the urban areas because their rural potential wage is greater than their actual urban wage. Without considering the rural unemployment rate, in the case of the unemployed, 98% have higher potential rural wages than reservation wages. For the informal workers, 45.81% have higher potential rural wages than current rural wages. This percentage is reduced to 28.71% in the case of formal wages. This situation arises because the migration decision between rural and urban areas does not depend only on economic factors, such as the probability of getting a job in urban areas and the wage differential, but also on non-economic factors such as the threats they and their families receive from the guerrillas and paramilitary groups.

The legalization of drugs leads to the cessation of the armed conflict in the first four scenarios considered. Then, for modeling migration after the shock, the non-economic factors associated with the conflict do not have to be taken into account. However, an initial equilibrium is estimated, where the workers select their preferred labor market, taking into consideration the unemployment rates and the costs of entry into the formal market. The interaction between the CGE model and the labor micro model is shown in figure 4.2. Changes in labor supplies are included in the CGE model, wages are calculated again, and the participation model is recalculated with the new wages until the model finds convergence. These feedback effects ensure the reduction of the bias generated when only one iteration is considered (Bourguignon and Savard, 2008).

4.3.2 The Almost Ideal Demand System (AIDS)

The second microeconometric model uses AIDS for the estimation of the consumer expenditure shares of the CGE model. The advantage of using AIDS over other linear demand systems, such as the Cobb-Douglas and the Linear Expenditure Function, is that price and income elasticities are not assumed to be the same for all households. AIDS was developed by Deaton and Muellbauer (1980a) as an alternative to the linear and the translog models that dominated the literature at the time.

Additionally, this paper considers two modifications to the original AIDS specification: the first one is the inclusion of a demographic component following the methodology developed by Ray (1983). The second one is the estimation of the model using censored data following the two-step method proposed by Shonkwiler and Yen (1999). A detailed description of these methodologies can be found in Appendix A. The modified estimable share with censored data and demographic variables is the following:

$$\begin{aligned} s_i = \quad & \Phi[\alpha_i + \textstyle\sum_{j=1}^{m} \gamma_{ij} \log p_j + (\beta_i + \theta i1 z_1 + \theta_{i2} z_2 + \theta i3 z_3)(\log w \\ & -(9 + \log(1 + \rho_1 z_1 + \rho_2 z_2 + \rho_3 z_3) + \log a))] + \delta\phi, \end{aligned} \tag{4.1}$$

where $\log a = \alpha_0 + \sum_{i=m}^{m} \alpha_i \log p_i + \frac{1}{2} \sum_{i=1}^{m} \sum_{j=1}^{m} \gamma_{ij} \log p_i \log p_j$.

The parameters of the model are α, β, γ, θ and ρ; s_i is the budget share of good i; p_i is the price of good i; and w is total expenditure. z_1, z_2 and z_3 are number of persons in the household, education of the household head and location (rural or urban) of the household, respectively; and δ is an extra parameter of the model with no restrictions. In order to maintain the additivity restriction of the shares, the system estimates n-1 equations, where n is the number of shares, and the last share is recovered as a residual of the $n-1$ shares.

The GEIH registers household expenditures of 1,055,945 goods and services, but unitary prices are only reported for the "food" category. Using price indices for 79 goods and services for low-, middle- and high-income households, prices are recovered following the methodology described in Appendix A. A price index is calculated following Urzua (2010) and the shares of the nine goods, and the total expenditures are recovered for each of the households in the survey. The AIDS model is estimated using a non-linear seemingly unrelated regression estimator (nlsur) where the shares are the dependent variables, and the prices, total expenditures, sociodemographic characteristics and the density functions (ϕ) are the independent variables. Results and details of this estimation are also found in Apprendix A.

The estimated shares are used as inputs in the CGE model and consumption is calculated using the prices and expenditures of the macro variables. This methodology follows Savard (2010), who uses AIDS for estimating the demand of a CGE model built for the Philippines. Because the GEIH does not provide information about the consumption of illegal drugs, its domestic consumption behavior is assumed to be the same as the consumption of tobacco and alcohol.

Once the CGE model is built and the shocks of legalizing drugs are calculated at the macroeconomic level, the economic welfare measures (equivalent and compensating variations) are calculated using the parameters of the AIDS model, changes in the income and prices of the CGE model, and recovering the expenditure and utility functions for each of the household groups. The equivalent (EV) and compensating (CV) variations are defined as follows:

$$EV(p^0, p^1, w) = e(p^0, u^1) - e(p^1, u^1) = e(p^0, u^1) - w, \tag{4.2}$$

$$CV(p^0, p^1, w) = e(p^0, u^0) - e(p^1, u^0) = w - e(p^1, u^0), \tag{4.3}$$

where $e(p^i, u^j)$ is the expenditure function estimated with prices i and utility j. The expenditure function is calculated using two different price indexes: $log(a)$ which was defined before in equation 4.1, and $b(p) = \prod_{i=1}^{n} pi^{\beta_i}$.

The EV and CV give information about the losses or gains on welfare by a price increase. Specifically,

the CV measures how much money the consumer would have to receive in order to offset the losses of the price increase, while the EV measures how much money the consumer would have to give away in order to have a loss equal to the price increase. Both measures answer the same problem: how much extra income is needed in order to offset the price changes. Then, *negative* EV and CV mean that the consumer receives a *gain* in economic welfare, and *positive* measures mean a *loss* in economic welfare.

4.4 Description of the CGE model: data used and simulations

4.4.1 Description of the data

The main source of data for the CGE model comes from the social accounting matrix (SAM). The SAM is built following Corredor and Pardo (2008) using Colombian data from 2006. All the information required for the construction of the aggregated SAM is provided by the Colombian National Department of Statistics (Departamento Administrativo Nacional de Estadistica, or DANE) in three tables: the utilization matrix, the supply matrix, and the general equilibrium matrix. The illegal drugs sector information and its linkage with the legal economy are provided by an "enclave" account also reported by DANE.

The production side is disaggregated into an illegal drugs sector and ten legal sectors: food, housing, clothing, health, education, culture, transportation (infrastructure), addictions (alcohol and tobacco), other services and security. All products, excepting the security and health services, are both imported and exported. The main exports come from the transportation and the food sectors (46% and 16% respectively), while the export of illegal drugs represents only 3.37% of the total exports. The highest level of imports is observed in the housing sector followed by transportation (44.35% and 17.93% of the total imports, respectively).

The Quality of Life Survey for 2003, the 2005 Census and the GEIH, all conducted by DANE, are used to disaggregate the factors of production and the demand side of the SAM. Corredor and Pardo (2008) also provide tables explaining how this disaggregation is accomplished. Households are divided into income deciles for both rural and urban areas, and labor is disaggregated into three different labor forces (rural labor, urban informal labor and urban formal labor), and unemployment.

The disaggregated SAM is rebalanced using the RAS method first developed by Stone and Brown (1962). Table 4.3 shows a simplified version of the 2006 SAM used as a benchmark economy for the development of the CGE model. Households are the owners of the factors of production and receive money from them. The illegal activity uses rural labor and a factor of production called the illegal factor which is not paid to the households but to the rest of the world. This account is called *income leakage* and essentially represents the

opportunity cost of the prohibition (money the households are not receiving because of the illegality of the drugs).

Tables 4.4 and 4.5 show the factors demand and factors supply respectively disaggregated for household types. Food, clothing, education, culture, transportation, alcohol and other services are considered capital-intensive sectors. Health and security are labor-intensive sectors and most of the labor used comes from the urban formal market. On the other hand, the urban informal market supplies most of the labor for the clothing industry and cultural services. The illegal drugs sector uses primarily the illegal factor for its production, but it also purchases 27.2% of their value added from rural labor. Most of the other activities use primarily urban labor, with the exception of the food industry which uses 15.2% of rural labor.

The SAM is built in a way that the urban households only provide urban labor and the rural households only provide rural labor. Most of the rural labor is supplied by the ninth income decile followed by the second and sixth income deciles. The highest proportions of urban informal and formal labor supplies are provided by the highest income deciles, but formal labor is more concentrated in the highest income deciles than informal labor. The tenth urban income decile supplies 59.2% of the total formal labor, while it provides just 32% of the total informal labor. The lowest deciles provide mainly informal labor. Capital is also concentrated in the urban areas, with higher provision from the highest income deciles. However, the highest proportion of capital is supplied by the non-financial institutions which provide 28.8% of the total capital in the economy.

4.4.2 The benchmark economy

The CGE model is drawn following one of the standard frameworks developed by the IFPRI (Lofgren et al., 2002) with additional modifications in order to suit the interests of this specific paper. Colombia is treated as a small-open economy where the international prices are given and are only affected by an exchange rate that is assumed to be flexible (fixed foreign savings). Producers and consumers maximize their profits and utility, respectively. Producers use Cobb-Douglas production functions that are estimated endogenously by the model. Consumption is also calculated endogenously using the shares of the AIDS model.

Constant elasticity of substitution functional forms are used to measure the imperfect substitution between imports and domestic output sold domestically (Armington function), and between exports and domestic output sold domestically (output transformation function). The elasticity of substitution between imports and domestic goods, and the elasticity of substitution between exports and domestic sales are set exogenously.

Capital is fully employed and not mobile, following the assumption that specific capital is needed for each

of the economic activities. The "illegal factor" is also fully employed and immobile because it cannot be used for any other economic activity. In both cases, the wage and the factor demand are fixed. Labor supplies in the rural areas and in the three different urban labor markets are set exogenously and are estimated using the labor participation model. Feedback loops are used between the labor participation model and the CGE model in order to achieve a stable equilibrium.[3]

The households receive money from the factors of production, transfers from the government and transfers from the rest of the world. The government receives income from taxes, tariffs, capital and transfers from the rest of the world; and spends it on consumption (of manufacturing, services, security and health), transfers to households, and savings (or investment depending on the sign of the account). Security is only purchased by the government because it is considered a public good provided by the state.

The model includes several closures. The investment is defined in terms of savings in order to satisfy the savings-investment quality, $SAV - INV = 0$; the capital and the illegal drugs are fully employed and not mobile, while the labor supplies are fully mobile in order to allow migration between different labor markets. Finally, the exchange rate is flexible and used to adjust prices and clear the current account, leaving the foreign savings fixed.

4.4.3 Simulation: Legalization of illegal drugs

The shocks applied to the economy simulate the legalization of drugs worldwide. Because the net effect of all these changes happening worldwide is uncertain, several scenarios are assumed.[4] One of the main shocks of drugs legalization is the end of the armed conflict, which would affect the economy in two ways. First, the government would not have to spend the same amount of money on security as before, and the U.S. would decrease its current military funding for Colombia. Second, it would decrease the importance of the non-economic factors in the rural-urban migration decision.

Regardless of the scenario considered, the following shocks are always assumed:

1. The production of drugs triples and it remains in the rural areas.

2. The illegal factor is distributed among the rural households under the assumption that the production of drugs is mainly a rural activity. The distribution of the illegal factor is made in the same proportion as for the rural labor.

[3] Convergence in all scenarios is achieved after three iterations.

[4] A decrease in the price would increase consumption, but effective health campaigns would decrease the consumption. Some other countries would become potential producers and competition could increase, reducing prices even more. On the other hand, consumption taxes, or other demand strategies, would decrease consumption. Changes in prices would be also dependent on how inelastic the international and domestic demands are.

3. Because the illegal factor is distributed nationwide, the amount of the "income leakage" is reduced to zero, eliminating the money laundering caused by the drugs prohibition.

4. The illegal sector pays the same rate of taxes as does the agricultural sector, a tax rate of 6.9%.

5. Military aid received from the U.S. to support the drug prohibition is reduced. Then, transfers from the rest of the world decrease by 30%.

6. In each scenario, changes in labor supply are included following the results estimated by the labor participation model.

Six scenarios are considered with specific shocks as explained in table 4.1:

Table 4.1: Description of the different scenarios considering different assumptions.

	Sc. 1	**Sc. 2**	**Sc. 3**	**Sc. 4**	**Sc. 5**	**Sc. 6**
End of armed conflict Security expenses: -30%	X	X	X	X		
Armed conflict continues					X	X
Export price of drugs is reduced by 20%	X	X			X	
Export price of drugs increases by 20%			X	X		X
No reinvestment of security in other sectors	X		X		(2)	(2)
Reinvestment of security in other sectors(1)		X		X	(1)	(1)

(1)The government doubles its expenditures in health services, and increases its expenditures in infrastructure and education by 20% each.
(2) The government maintains its expenditures in security and doubles its expenditures in the health sector.

4.5 Analysis of the results

Tables 4.6 to 4.9 show the macroeconomic impacts of the legalization of drugs leading to the end of the armed conflict ends. The results suggest that the changes in the economy are strongly dependent on the reinvestments of the security expenses the government makes once the drugs are legalized. In most cases, rural households experience an increase in their income due to the higher production of drugs and the distribution of the "illegal factor" among the household groups. These changes are lower when the export price of drugs increases, due to the reduction of the exports of drugs. When the government does not reinvest the security money in other productive sectors, income in the urban areas decreases, with the highest income deciles being the most affected. Without government reinvestment, urban formal wages are reduced by 9.07%

when the export price of drugs is reduced, and by 8.86% when the export price of drugs increases. These reductions in the urban formal wage also decrease urban labor by 2.67% and 3.09%, respectively, causing the migration of formal workers to the informal market and to the rural areas.

When legalization ends the armed conflict, the best scenarios in terms of income are the scenarios that simulate a reinvestment of the security expenses in the health, education and transportation sectors, even if the export price of drugs is reduced (scenario 2). In these cases, most of the rural and urban households experience an increase in their income, with the higher increases in the highest urban deciles and in the lowest rural deciles. When the government reinvests the security expenses, urban areas are reactivated with more jobs and greater wages. Rural-urban migration increases until the point that the expected urban wage is equal to the rural wage. The highest increases are observed in the formal urban wage: 11.44% with a reduction of the export price of drugs, and 11.89% with an increase in the export price of drugs. These increases in the formal urban wage cause a reduction of the formal labor of 3.72% and 4.10% respectively. The rural wage also increases because of the government reinvestments, and the rural labor supply goes up as a consequence of the higher rural wage and the higher production of illegal drugs. The rural labor increases more when the export price of drugs increases (5.54%), than when the price decreases (3.74%).

When the armed conflict does not end with legalization, and the export price of drugs increases, the benefits in income are even higher for both rural and urban areas as shown in table 4.11 (with exception of the 10th rural decile that has an income reduction). The ongoing armed conflict increases the economic activity and maintains the country in an "economy of war" situation, where the government military expenditures are creating jobs in both rural and urban areas. However, if the legalization reduces the export price of drugs, the highest rural deciles and the lowest urban deciles are affected by receiving a lower income, even if the government maintains their expenses on security, a situation that is shown in table 4.10. Urban formal wages increase in these two scenarios by 12.72% when the export price of drugs decreases, and by 14.29% when the export price of drugs increases. These increases in the formal urban wage cause a reduction in formal labor of 3.12% and 3.41% respectively, causing migration to the informal and rural markets.

The changes to the supply side of the economy more directly reflect the external shocks assumed in the different scenarios: the composite price of illegal drugs is reduced when the export price of drugs is reduced, but in a lower proportion because the exports are substituted by domestic consumption. In a similar way, when the export price of drugs increases, the composite price increases even more because of an increase of the product sold domestically. The reinvestment of the government expenditures in health, education and transportation are reflected in higher production of these sectors in scenarios 2 and 4. The security supply is reduced in the first four scenarios, as a consequence of the government reduction on military

expenses. When the armed conflict continues after legalization (scenarios 5 and 6), the only sector that receives government investments is the health sector, because it is assumed that after legalization, health campaigns and prevention plans to control addiction would be necessary. The health supply increases by 41.76% and 41.84% in scenarios 5 and 6, respectively, also increasing the price of health services.

The changes in the GDP after legalization under the six different scenarios provide a clearer idea about the economic costs of the drug prohibition. Contrary to the estimates observed in the literature (see Echeverry, 2004) that estimates the net earnings of the drug business to be 2.3% of the GDP, the results of these simulations suggest that the costs or the benefits of legalization are always below 2% of the Colombian GDP. The best scenario, in terms of GDP growth, is the scenario in which the export price of drugs increases and the government continues its military expenses because of the perpetuation of the war (scenario 6). In this case, the GDP increases by 1.48%. If the war continues, but the export price of drugs is reduced, the GDP increases by only 0.40%. When legalization ends the armed conflict, and the government does not reinvest the military expenses in other productive sectors, the GDP is reduced by 1.04% if the export price of drugs decreases, and by 1.21% if the export price of drugs increases. With government reinvestment in health, education and transportation, the GPD increases by 0.35% with a reduction of the export price of drugs, and by 0.20% with an increase in the export price of drugs.

In terms of household economic welfare, the best scenario is observed when the armed conflict does not end with the legalization, and the export price of drugs decreases. In this case, both rural and urban areas receive welfare gains, with greater gains in the lower income deciles. While the highest rural decile received a median welfare gain of 0.119%, the lowest rural decile receives a gain of 0.166%. Benefits are greater in the urban areas, but again, the poorest households receive greater gains than the richest households. In general, most of the scenarios improve the economic welfare of rural and urban households, and in most of the cases, the distribution of these gains is not monotonic with income, with the poorest households benefitting more than the richest households. The only two scenarios where welfare losses are observed are when the armed conflict ends with the legalization and the government does not reinvest the security expenses in other productive sectors. In these cases, both with an increase or a reduction of the export price of drugs, the highest rural deciles (deciles 8th, 9th and 10th), and the highest urban deciles (deciles 7th, 8th, 9th and 10th) have a reduction of their economic welfare.

To analyze the total benefits of the legalization of drugs in terms of welfare, the median equivalent and compensated variation must be multiplied by the number of households in each of the deciles.[5] The best scenario in terms of welfare is scenario 5, which assumes the perpetuation of the armed conflict and the

[5]Not only by the number of observations that are included in the survey, but also by their expansion factors to have an accurate representation of the total number of households in the country.

reduction of the export price of drugs. In this case the economic welfare increases by US$3.142 million dollars. The second-best scenario in terms of welfare is scenario 2 that assumes the end of the armed conflict with a reduction of the export price of drugs, and the reinvestment of security expenses in other productive sectors. The welfare gains in this case are US$3.056 million dollars. When legalization ends the armed conflict and the government does not reinvest the security expenses, the total welfare losses are US$12,288 dollars when the export price of drugs is reduced, and US$150,121 dollars when the export price of drugs increases. A summary of the total welfare loses and gains in each of the scenario is described in table 4.14.

4.6 Concluding remarks and further research

In this paper, a CGE model is used to simulate the economic welfare effects of drug legalization on a producer country using Colombian data for 2006. Six different scenarios with different assumptions about the consequences of the drug legalization are evaluated. In the specific case of Colombia, where the drug market is directly related to the perpetuation of the armed conflict and the economic disparities between rural and urban areas, the end of the conflict is an important assumption in some of the scenarios.

The results suggest that the economic welfare of rural and urban households is slightly improved with the legalization of drugs, but only when the government reinvests the money not spent in security services in other productive sectors, such as infrastructure, education and health, or when the legalization does not end the armed conflict. Both in terms of total amount of welfare gained and redistribution of welfare gains, the best scenario is when the export price of drugs decreases, and the armed conflict is perpetuated. This situation is explained because the government is constantly investing in military expenditures, creating new job opportunities and maintaining the economy in an "economy of war" situation. When legalization ends the armed conflict and it is not accompanied with government reinvestments in other productive sectors, the highest urban and rural deciles are worse off in terms of economic welfare, even if the export price of drugs increases.

The use of microsimulation models to complement the shocks implemented in the CGE model is an essential part of the analysis. Economic welfare in rural and urban areas is affected by the changes in the level of prices and wages, and wages are affected by the labor supply in rural, informal and formal markets. The labor participation model allows for endogenously determining the labor supply in different sectors given the changes in wages provided by the CGE model. On the other hand, the econometric estimation of an AIDS model provides two advantages to the simulation of the legalization of drugs. First, the budget shares for the twenty household groups are estimated econometrically without the assumption of linear Engel curves

and homogeneous income elasticities for all households. Secondly, the welfare measures are calculated at the microeconomic level. Once changes in income and prices are estimated in the CGE model, welfare gains or losses of the legalization of drugs can be analyzed.

Economic welfare in this exercise is measured by changes in prices and income, given by the definitions of the EV and CV measurements. However the analysis ignores the utility from the provision of more public goods such as education and health and how the human capital is improved by increasing the consumption of these services. Similarly, the welfare calculation does not consider the noneconomic effects and the social costs of war and drug consumption. The civil war in Colombia represents a threat to the population in terms of fear, kidnappings and deaths among others. On the other hand, an increasing consumption and production of drugs would increase addiction rates among the population affecting social and family networks, and labor productivities. If these effects would have taken into consideration when estimating the economic welfare, continuing with the armed conflict would not have been the best scenario when drugs are legalized.

Further work will analyze the effect of cutting the security expenses and reducing the transfers from the rest of the world to the government. Although most of the funding from the Plan Colombia was to finance military expenses, during the last years, the relationship between the Colombian and the American government has changed, and now the transfers from the U.S. are more directed to finance alternative development plans to eradicate illegal drugs production such as crops substitution programs and allocation of land to the direct victims of the conflict. Because the cut of security expenses is such an important determinant of this paper's results, new simulations will be calculated by changing the purpose of the American funding to the Colombian government to estimate new economic welfare effects.

There are many possible ways the research agenda could be extended. For example, the results focusing on households' welfare are limited to the economic consequences of the legalization of drugs without considering the social effects of a rise in drug consumption. Even if the economy is reactivated by a higher production of drugs and a greater demand of health services or military expenses, the consumption of drugs affects the social networks in a community and creates productivity problems in the long-run. The results would have greater policy relevance if the social effects of drugs consumption are included. By simulating a "long-run" scenario in which the consumption of drugs is spread among the population, changes in productivity can be estimated to measure the negative social effects of drug consumption in the economy. Other alternatives to legalization could also be simulated, such as the implementation of social programs and alternative development crops, programs that are already taking place in Colombia as part of the Plan Colombia. This economic exercise is useful, not only for the Colombian government when negotiating anti-drug policies with developed consuming countries, but also for other developing countries that are affected by the illegal drug

production and trafficking. The model built for Colombia can be replicated in other countries to estimate the effects of the illegal drug markets in regional economies, and to consider the inter-national impacts of alternative combinations of assumptions about demand-side management and supply-side options in relation to drug production.

Figure 4.1: Model structure: interaction between micro models and CGE model

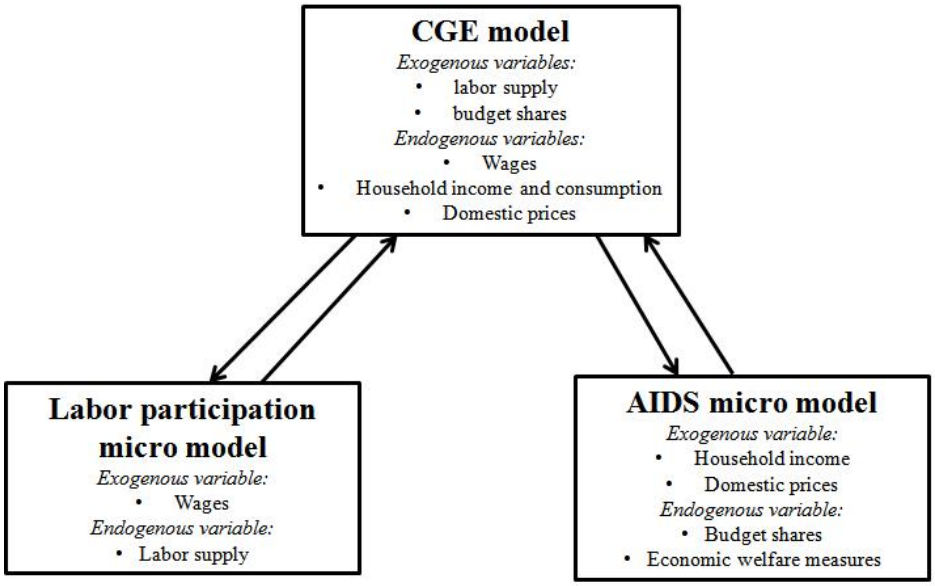

Table 4.2: Summary of statistics of demographic characteristics of households by labor sector

	Labor sectors			
	Rural	Unemployed	Informal	Formal
Ln wage	14.78	0	14.08	14.95
	(1.64)	(0)	(3.23)	(3.12)
Male (%)	0.71	0.45	0.68	0.75
	(0.45)	(0.50)	(0.47)	(0.44)
Age HH head	48.13	57.63	45.73	41.21
	(15.70)	(17.12)	(12.62)	(41.21)
Education	2.65	3.25	3.47	4.52
1-6 (low-max)	(1.81)	(1.82)	(1.72)	(1.54)
Number of kids	3.76	3.59	3.75	3.47
(¡3 years old)	(1.96)	(2.04)	(1.86)	(1.61)
Husband (%)	0.64	0.43	0.63	0.69
or wife	(0.48)	(0.49)	(0.48)	(0.46)
Working persons	1.40	0.91	1.77	1.67
in HH	(0.94)	(1.04)	(0.93)	(0.82)

Figure 4.2: Interaction between the labor participation model and the CGE model: Estimation of wages and labor supplies

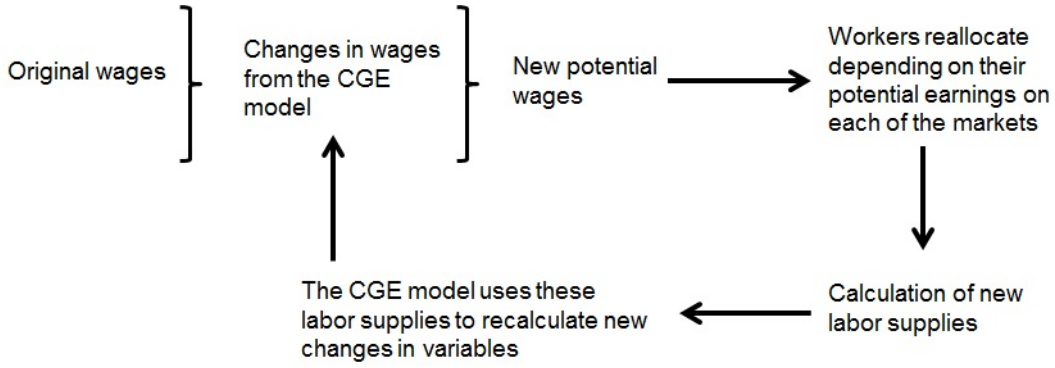

Table 4.3: Colombian 2006 Social Accounting Matrix with illegal drugs

		1...11	12...22	23...27	28...49	50	51	52...54	55	Total
Activities	1. Illegal 2. Food 3. Housing 4. Clothing 5. Health 6. Education 7. Culture 8. Transp. 9. Alcohol 10. Other ss 11. Security		Product.				Invest.			
Goods	12 - 22	Int.Cons.			Consumpt.	Consumpt.			Exports	
Factors of Production	23. Rural labor 24. Informal labor 25. Formal labor 26. Capital 27. Illegal factor	Value Added		Income from factors of produc.						
Institutions	28. Non-financial firms 29. Financial firms 30. Rural HH decile 1 31. ... 38. 39. Rural HH decile 10 40. Urban HH decile 1 41. ... 48. 49. Urban HH decile 10				Transfers	Transfers			Transfers	
	50. Government 51. Savings-Investment 52. Income tax 53. Sales tax 54. Tariffs 55. ROW		Taxes Tariffs Imports	Inc.leakage	Savings taxes	Savings		Revenue	Transfers Ext.savings	
TOTAL										

Table 4.4: Proportion of factors of production used for each economic activity

	Rural labor	Informal urban	Formal urban	Capital	
illegal	27.2%	0.0%			72.8%
food	15.3%	8.5%	8.0%	68.2%	
housing	0.9%	10.6%	8.8%	79.6%	
clothing	2.6%	36.4%	9.3%	51.7%	
health	3.0%	10.6%	59.1%	27.3%	
education	6.4%	22.5%	31.4%	39.7%	
culture	2.4%	27.5%	12.2%	57.9%	
transp	0.8%	6.4%	7.0%	85.8%	
alcohol	1.0%	3.4%	29.0%	66.6%	
other	0.0%	5.0%	31.2%	63.8%	
security	2.8%	0.4%	74.9%	21.9%	

Table 4.5: Proportion of each of the factors of production received by each institution

	Rural labor	Informal urban	Formal urban	Capital
non-financ				28.8%
financial				2.1%
rural HH1	7.6%			0.2%
rural HH2	12.5%			0.3%
rural HH3	10.8%			0.7%
rural HH4	9.0%			0.9%
rural HH5	9.1%			0.9%
rural HH6	12.1%			1.0%
rural HH7	10.0%			1.0%
rural HH8	7.3%			1.3%
rural HH9	12.9%			1.2%
rural HH10	8.8%			1.9%
urban HH1		0.9%	0.2%	0.4%
urban HH2		3.5%	0.5%	1.0%
urban HH3		5.1%	0.7%	1.9%
urban HH4		7.1%	1.6%	2.2%
urban HH5		7.5%	2.6%	2.7%
urban HH6		8.0%	3.6%	4.3%
urban HH7		9.1%	6.1%	5.1%
urban HH8		13.6%	10.0%	6.9%
urban HH9		13.2%	15.4%	11.5%
urban HH10		32.0%	59.2%	23.8%

Table 4.6: Results scenario 1: End of armed conflict, reduction in the export price of drugs and no government reinvestment (% CHANGES)

Demand side			**Supply side**			**Macro variables**		
	Income			Supply	Price			
Deciles	Rural	Urban	ILL	66.97	-3.88	GDP	-1.04	
1st	-0.34	0.28	FOOD	0.10	-0.10	Private cons.	-1.26	
2nd	-0.40	0.12	HOUS	3.94	0.57	Public cons.	-24.01	
3rd	0.05	0.25	CLOTH	0.62	0.70	Investment	8.59	
4th	0.21	-0.23	HEALTH	0.18	-2.99			
5th	0.20	-1.60	EDU	0.00	-1.37	**Labor Market**		
6th	0.09	-0.60	CULT	0.18	0.39		**Wages**	**Labor supply**
7th	0.22	-1.10	TRANS	2.87	-0.09	Rural	-2.84	3.74
8th	0.36	-1.49	ALCOH	2.08	0.57	Unemployed		-7.84
9th	0.09	-1.43	OTR	-4.28	-0.93	Informal	4.02	2.99
10th	0.44	-2.87	SECUR	-45.51	-4.14	Formal	-9.07	-2.67

Table 4.7: Results scenario 2: End of armed conflict, reduction in the export price of drugs and government reinvestment (% CHANGES)

Demand side			**Supply side**			**Macro variables**		
	Income			Supply	Price			
Deciles	Rural	Urban	ILL	200.21	-6.81	GDP	0.35	
1st	2.23	-0.01	FOOD	-0.94	0.10	Private cons.	1.43	
2nd	2.35	0.45	HOUS	-18.92	-0.77	Public cons.	50.91	
3rd	0.83	-0.10	CLOTH	-2.41	1.00	Investment	-43.26	
4th	-0.02	0.77	HEALTH	107.91	3.84			
5th	0.14	1.00	EDU	25.93	2.79	**Labor Market**		
6th	0.44	0.54	CULT	0.15	0.49		**Wages**	**Labor supply**
7th	0.06	1.12	TRANS	3.42	-1.21	Rural	4.52	4.77
8th	-0.92	1.67	ALCOH	7.00	0.38	Unemployed		-10.30
9th	0.09	1.22	OTR	-5.05	0.73	Informal	5.88	4.75
10th	-1.41	3.02	SECUR	-31.29	4.50	Formal	11.44	-3.72

Table 4.8: Results scenario 3: End of armed conflict, increase in the export price of drugs and no government reinvestment (% CHANGES)

Demand side			**Supply side**			**Macro variables**		
	Income			Supply	Price			
Deciles	Rural	Urban	ILL	67.15	23.75	GDP	-1.21	
1st	-0.22	0.16	FOOD	-0.09	-0.10	Private cons.	-1.40	
2nd	-0.29	-0.02	HOUS	3.64	0.48	Public cons.	-23.93	
3rd	0.10	0.10	CLOTH	0.25	1.09	Investment	8.27	
4th	0.22	-0.40	HEALTH	0.13	-2.88			
5th	0.23	-0.76	EDU	-0.22	-1.07	**Labor Market**		
6th	0.12	-0.76	CULT	-0.10	0.48		**Wages**	**Labor supply**
7th	0.24	-1.27	TRANS	2.54	-0.19	Rural	-3.60	4.51
8th	0.29	-1.66	ALCOH	2.78	0.09	Unemployed		-8.85
9th	0.05	-1.61	OTR	-4.44	-1.02	Informal	5.59	2.65
10th	0.33	-3.03	SECUR	-45.49	-4.03	Formal	-8.86	-3.09

Table 4.9: Results scenario 4: End of armed conflict, increase in the export price of drugs and government reinvestment (% CHANGES)

Demand side			**Supply side**			**Macro variables**		
	Income			Supply	Price			
Deciles	Rural	Urban	ILL	66.67	21.02	GDP	0.20	
1st	2.30	-0.14	FOOD	-1.13	0.10	Private cons.	1.30	
2nd	2.41	0.31	HOUS	-23.93	-0.77	Public cons.	33.83	
3rd	0.88	-0.25	CLOTH	2.86	1.28	Investment	-77.91	
4th	-0.02	0.61	HEALTH	51.89	3.87			
5th	0.18	0.85	EDU	20.44	2.89	**Labor Market**		
6th	0.47	0.39	CULT	-0.14	0.58		**Wages**	**Labor supply**
7th	0.09	0.97	TRANS	2.94	-1.32	Rural	3.85	5.54
8th	-1.00	1.51	ALCOH	7.06	-0.19	Unemployed		-11.31
9th	0.04	1.06	OTR	-5.49	0.73	Informal	7.32	4.25
10th	-1.55	2.84	SECUR	-45.51	4.39	Formal	11.89	-4.10

Table 4.10: Results scenario 5: The armed conflict continues, unchanged security expenses and reduction of the export price of drugs (% CHANGES)

Demand side			**Supply side**			**Macro variables**		
	Income			Supply	Price			
Deciles	Rural	Urban	ILL	66.90	-5.71	GDP	0.40	
1st	1.22	-0.17	FOOD	0.39	-0.19	Private cons.	1.28	
2nd	1.25	-0.21	HOUS	-13.92	-0.38	Public cons.	24.63	
3rd	0.21	-0.63	CLOTH	-1.63	0.50	Investment	-40.97	
4th	-0.47	0.09	HEALTH	41.76	4.15			
5th	-0.37	0.50	EDU	0.44	2.63	**Labor Market**		
6th	-0.15	0.28	CULT	-0.25	0.39		**Wages**	**Labor supply**
7th	-0.44	0.97	TRANS	-2.63	-1.32	Rural	2.30	4.52
8th	-1.12	1.48	ALCOH	4.96	0.85	Unemployed		-9.23
9th	-0.45	1.36	OTR	-0.60	1.18	Informal	3.21	3.13
10th	-1.56	3.16	SECUR	0.06	4.92	Formal	12.72	-3.12

Table 4.11: Results scenario 6: The armed conflict continues, unchanged security expenses and increase of export price of drugs (% CHANGES)

Demand side			**Supply side**			**Macro variables**		
	Income			Supply	Price			
Deciles	Rural	Urban	ILL	67.08	22.28	GDP	1.48	
1st	2.37	0.42	FOOD	1.49	-0.19	Private cons.	2.26	
2nd	2.49	0.57	HOUS	-12.56	-0.29	Public cons.	24.93	
3rd	1.42	0.18	CLOTH	0.28	-0.70	Investment	-38.20	
4th	0.81	1.03	HEALTH	41.84	4.32			
5th	0.99	1.43	EDU	1.35	1.98	**Labor Market**		
6th	1.16	1.20	CULT	1.09	-0.19		**Wages**	**Labor supply**
7th	0.95	1.93	TRANS	-2.19	-0.75	Rural	2.88	5.37
8th	0.04	2.47	ALCOH	6.86	0.28	Unemployed		-10.31
9th	0.86	2.34	OTR	-0.19	1.71	Informal	-3.32	2.47
10th	-0.28	4.13	SECUR	0.03	5.76	Formal	14.29	-3.41

Table 4.12: Comparison of the compensated variation measures and the expenditures percentage changes for the six different scenarios.

	Scenario 1		**S**cenario2		**S**cenario 3		**S**cenario 4		**S**cenario 5		**S**cenario 6	
Rural	CV	CV ch.	CV	CV ch.	CV	CV ch.	CV	CV ch.	CV	CV ch.	CV	CV ch.
1st	-97.71	-0.046%	-339.33	-0.158%	-58.52	-0.027%	-294.88	-0.137%	-356.27	-0.166%	-309.459	-0.144%
2nd	-98.46	-0.044%	-349.69	-0.157%	-58.62	-0.026%	-304.44	-0.137%	-367.01	-0.165%	-319.339	-0.144%
3rd	-100.72	-0.039%	-394.44	-0.154%	-58.28	-0.023%	-345.98	-0.135%	-413.34	-0.161%	-362.185	-0.141%
4th	-101.42	-0.035%	-442.21	-0.151%	-56.62	-0.019%	-390.75	-0.133%	-462.70	-0.158%	-408.257	-0.139%
5th	-99.47	-0.029%	-512.17	-0.147%	-51.94	-0.015%	-457.06	-0.131%	-534.80	-0.154%	-476.293	-0.137%
6th	-86.74	-0.019%	-646.49	-0.141%	-36.12	-0.008%	-586.63	-0.128%	-672.68	-0.147%	-608.65	-0.133%
7th	-74.88	-0.014%	-721.62	-0.138%	-23.68	-0.005%	-660.29	-0.126%	-749.51	-0.143%	-683.595	-0.131%
8th	-48.42	-0.008%	-845.76	-0.134%	2.08	0.000%	-783.71	-0.124%	-876.05	-0.138%	-808.744	-0.128%
9th	62.59	0.007%	-1183.32	-0.125%	101.76	0.011%	-1129.05	-0.119%	-1217.73	-0.128%	-1156.52	-0.122%
10th	248.64	0.019%	-1563.61	-0.117%	260.33	0.019%	-1533.35	-0.115%	-1598.95	-0.119%	-1560.02	-0.117%
Urban												
1st	-86.44	-0.023%	-648.69	-0.175%	-35.79	-0.010%	-588.78	-0.159%	-674.94	-0.182%	-610.843	-0.165%
2nd	-54.47	-0.011%	-820.52	-0.167%	-3.67	-0.001%	-758.44	-0.155%	-850.36	-0.173%	-783.164	-0.160%
3rd	-97.21	-0.032%	-547.80	-0.181%	-48.59	-0.016%	-491.15	-0.162%	-571.44	-0.189%	-511.189	-0.169%
4th	-84.97	-0.023%	-659.13	-0.175%	-34.20	-0.009%	-598.96	-0.159%	-685.62	-0.182%	-621.215	-0.165%
5th	-75.33	-0.018%	-719.07	-0.172%	-24.14	-0.006%	-657.77	-0.157%	-746.91	-0.178%	-681.043	-0.163%
6th	-66.10	-0.015%	-767.37	-0.169%	-14.92	-0.003%	-705.53	-0.156%	-796.21	-0.176%	-729.533	-0.161%
7th	-14.44	-0.002%	-968.37	-0.162%	33.47	0.006%	-907.56	-0.151%	-1000.54	-0.167%	-933.846	-0.156%
8th	8.82	0.001%	-1039.96	-0.159%	54.40	0.008%	-980.72	-0.150%	-1073.02	-0.164%	-1007.55	-0.154%
9th	102.68	0.012%	-1276.92	-0.152%	136.46	0.016%	-1227.14	-0.146%	-1311.91	-0.156%	-1254.74	-0.150%
10th	621.64	0.040%	-2116.29	-0.135%	568.66	0.036%	-2146.54	-0.136%	-2146.70	-0.137%	-2166.11	-0.138%

Table 4.13: Comparison of the equivalent variation measures and the expenditures percentage changes for the six different scenarios.

	Scenario 1		**S**cenario2		**S**cenario 3		**S**cenario 4		**S**cenario 5		**S**cenario 6	
Rural	EV	EV ch.	EV	EV ch.	EV	EV ch.	EV	EV ch.	EV	EV ch.	EV	EV ch.
1st	-97.59	-0.045%	-343.81	-0.160%	-58.51	-0.027%	-299.43	-0.139%	-357.78	-0.167%	-314.28	-0.146%
2nd	-98.34	-0.044%	-354.67	-0.160%	-58.61	-0.026%	-309.45	-0.139%	-368.68	-0.166%	-324.65	-0.146%
3rd	-100.70	-0.039%	-395.00	-0.154%	-58.28	-0.023%	-346.91	-0.136%	-411.66	-0.161%	-364.79	-0.143%
4th	-101.41	-0.035%	-439.70	-0.150%	-56.59	-0.019%	-388.66	-0.133%	-458.26	-0.157%	-409.02	-0.140%
5th	-99.46	-0.029%	-510.04	-0.147%	-51.88	-0.015%	-455.48	-0.131%	-530.22	-0.152%	-477.99	-0.137%
6th	-86.74	-0.019%	-645.59	-0.141%	-36.05	-0.008%	-586.21	-0.128%	-668.36	-0.146%	-611.81	-0.133%
7th	-74.71	-0.014%	-718.41	-0.137%	-23.44	-0.004%	-657.60	-0.126%	-743.03	-0.142%	-685.93	-0.131%
8th	-47.85	-0.008%	-835.29	-0.132%	2.55	0.000%	-772.95	-0.122%	-863.82	-0.137%	-805.13	-0.127%
9th	63.06	0.007%	-1179.02	-0.124%	102.09	0.011%	-1124.31	-0.118%	-1207.99	-0.127%	-1159.92	-0.122%
10th	252.38	0.019%	-1539.52	-0.115%	262.83	0.020%	-1505.53	-0.112%	-1572.87	-0.117%	-1549.46	-0.116%
Urban												
1st	-86.75	-0.023%	-657.49	-0.177%	-36.00	-0.010%	-598.03	-0.161%	-678.21	-0.183%	-620.52	-0.167%
2nd	-55.17	-0.011%	-832.54	-0.170%	-4.11	-0.001%	-771.16	-0.157%	-854.86	-0.174%	-796.48	-0.162%
3rd	-97.23	-0.032%	-548.74	-0.181%	-48.57	-0.016%	-492.57	-0.162%	-569.35	-0.188%	-514.97	-0.170%
4th	-84.87	-0.022%	-655.69	-0.174%	-34.04	-0.009%	-595.90	-0.158%	-679.43	-0.180%	-622.53	-0.165%
5th	-75.19	-0.018%	-716.35	-0.171%	-23.92	-0.006%	-655.63	-0.156%	-740.87	-0.177%	-683.61	-0.163%
6th	-66.04	-0.015%	-766.44	-0.169%	-14.78	-0.003%	-705.10	-0.156%	-791.28	-0.175%	-733.40	-0.162%
7th	-13.92	-0.002%	-964.39	-0.161%	34.05	0.006%	-904.04	-0.151%	-992.32	-0.166%	-937.20	-0.156%
8th	9.89	0.002%	-1027.39	-0.157%	55.23	0.008%	-967.41	-0.148%	-1058.43	-0.162%	-1003.20	-0.154%
9th	103.30	0.012%	-1272.39	-0.152%	136.89	0.016%	-1222.05	-0.146%	-1301.57	-0.155%	-1258.49	-0.150%
10th	629.20	0.040%	-2084.90	-0.133%	573.53	0.036%	-2108.17	-0.134%	-2113.18	-0.134%	-2152.01	-0.137%

Table 4.14: Total welfare gains and loses by scenario

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Total EV (Colombian pesos)	35,637,976.84	(8,863,591,240.37)	435,352,115.36	(8,339,819,206.94)	(9,113,408,949.59)	(8,635,128,027.02)
Total EV (US dollars)	12,288.96	(3,056,410.77)	150,121.42	(2,875,799.73)	(3,142,554.81)	(2,977,630.35)
proportion of Colombian GDP	9.04751E-11	-2.25597E-08	1.10516E-09	-2.12282E-08	-2.3187E-08	-2.1975E-08
Total CV (Colombian pesos)	27,006,336.66	(8,905,831,274.23)	429,201,806.82	(8,386,454,312.27)	(9,191,973,885.62)	(8,618,961,793.91)
Total CV (US dollars)	9,312.53	(3,070,976.30)	148,000.62	(2,891,880.80)	(3,169,646.17)	(2,972,055.79)
proportion of Colombian GDP	0.00	(0.00)	0.00	-2.13469E-08	-2.33869E-08	-2.19338E-08

Appendix A

Linkages between CGE, Almost Ideal Demand System and labor participation models

A.1 Introduction

Policy makers have increased their interest in the distributional effects of macro policy shocks. Since the 1970s, the World Bank has established the reduction of world poverty as a goal for development, and several authors have stated the importance of including distributional effects as goals for economic growth and development (Ravallion, 2001; Barro, 2000). However, when analyzing the effects of macroeconomic policies on the economy, the aggregate or national accounts ignore the effect that policies may have on individual household groups. Recently, the literature has been more concerned to find a way to evaluate the distributional effects of a macroeconomic shock by linking national and aggregate accounts with household level data.

The uses of general equilibrium frameworks to evaluate the impacts of macro policies have several explanations: the first one is related to the nature of the policy analyzed (Bourguignon et al., 2008). When the policy has a macroeconomic nature, a general equilibrium is needed, but the effect is different for every household group. The second one is related to the methodology used to evaluate a policy impact. When doing *ex post* impact evaluation analysis, control and treatment groups are defined using different econometric techniques, and the output of the treatment is compared to the output of the control group. However, if an *ex ante* analysis is needed for a macro policy, defining control and treatment groups is not an easy task, because all the households are affected by the policy, and secondly, because none of the households has received the treatment yet.

In this paper, a methodology to analyze the impacts of an *ex ante* macroeconomic shock is described by linking a general equilibrium model with microeconomic models that account for the different responses of households to the macro shock. Two microeconomic models are used to simulate the households' behavior: the first one is a segmented labor participation model using a Heckman two-step methodology (Magnac, 1991); the second one is an Almost Ideal Demand System (AIDS), first developed by Deaton and Muellbauer (1980b). The labor participation model includes behavioral responses in the sense that the household

responds to second and third-round effects of changes in the macro model. The AIDS uses as an accounting approach without second-round effects, but it is later used also to calculate welfare measures at the household level, taking into consideration the changes in income and prices of the CGE model. An application of this methodology using Colombian data for 2006 shows that the microeconomic labor model and the CGE model converge after three iterations, and the results can be easily used to calculate economic welfare measures at the household level.

The paper is divided as follows. The first section below presents a description of the labor participation model. Then, section A.3 describes the AIDS model used to estimate household demands. Section A.4 describes the social accounting matrix (SAM) and the CGE model used to estimate the macro shocks to the economy using Colombian data for 2006. The linkages between the two microeconomic models and the CGE model are described in section A.5. Finally, section A.6 provides some concluding remarks.

A.2 The labor participation model

When analyzing the effects that a macroeconomic shock has on households' welfare, the labor market is one of the conduits through the different household types are affected. Households are assumed to be working in one of the labor markets in the economy, and in some cases, when the wages of these markets are affected, households decide to migrate to other labor markets because the expected gains there are greater than their actual earnings. Migration in this case is understood as a movement from one segmented market to another (formal vs. informal), or from one region to other one (rural vs. urban). Migration between labor markets is modeled using a labor participation framework following Magnac (1991), Savard (2003) and Cogneau and Robilliard (2006) on segmented labor markets.

In this specific case, changes in wages are assumed to be exogenous to the labor participation model because they are estimated in the CGE model. Then, the labor participation model uses these wage changes to calculate changes in labor supply and migration flows across different labor markets. The urban areas are disaggregated into three components: unemployed and two labor markets: informal labor and formal labor. The rural areas only have rural labor, but it is assumed that the rural unemployment rate is 10%.[1]

The model uses the Integrated Household Survey of Income and Expenses (GEIH) of 2007 for Colombia. The Survey was conducted in both rural and urban areas collecting information about the demographic, income, expenses and labor characteristics of 64,119 different households. Most of the information is available at the household level and disaggregated information is also available for the household head. The labor participation model uses labor and demographic characteristics of the household heads, assuming that the

[1]Households consider this unemployment level by calculating their potential rural wage as the 90% of the monetary wages.

labor choices of other household members are the same.

Table A.1 shows a summary of the statistics of the labor market at the initial equilibrium, with 45.80% of the total households in the rural sector and 54.19% in the urban sectors. From the urban households, 28.74% are unemployed, 30.95% belong to the informal sector, and 40.37% to the formal sector. Rural workers have the lowest level of education, and most of the unemployed are women. Highest wages are earned by the formal workers followed by the rural workers and the informal workers. Notice that the informal wages are lower than the rural wages suggesting an incentive to migrate from the urban informal market to the rural areas.[2]

In order to determine the direction of the migration flows, the Heckman two-step method with a bivariate Probit in the first step is used to estimate the probability of a worker being employed in each of the labor markets. The first Probit estimation determines whether the worker is employed in rural or in urban areas. The second one, determines in which of the urban labor markets or rural labor market (rural vs. unemployment), the worker is employed. Because these probabilities are dependent on each other, a bivariate Probit considers the correlation of the error terms of the two equations. The model can be specified as follows:

$$Y_{1i}^{*} = X_{1i}\beta_1 + \mu_{1i} \qquad Y_{2i}^{*} = X_{2i}\beta_2 + \mu_{2i}, \tag{A.1}$$

where,

$$\mu_{1i} = \eta_i + \epsilon_{1i} \qquad \mu_{2i} = \eta_i + \epsilon_{2i}, \tag{A.2}$$

and X_1 and X_2 are characteristics of the households such as household head gender, age, education, marital status, other income of the household, number of persons and number of occupied persons.

In the specific case of the urban formal workers, $Pr(Y_{1i} = 1)$ is the probability of being employed in the urban areas, and $Pr(Y_{2i} = 1)$ is the probability of being employed in the urban formal labor market rather than in the informal market, or being unemployed. Similar analyses are conducted for the informal workers, urban unemployed and rural workers. The results of the bivariate Probit models are shown in table A.2. A higher socioeconomic status, as well as higher level of education, and having other sources of income different than wages, increases the probability of a worker being employed in urban areas, in any of the urban labor markets. Larger families are more likely to be found in rural areas, but with greater chances of being unemployed. When more members of the family are working, the probability of the household being located in urban areas is greater. Finally, older household heads are less likely to be employed in the rural areas or in the formal markets, increasing the probability of unemployment and informal employment in the

[2]This situation could be explained by the noneconomic factors that affect the migration decision of households such as the existence of an armed conflict in the countryside.

cities.

Once the bivariate Probits are estimated, Mills ratios for each of the labor markets are calculated as the ratio between the probability density function and the cumulative density function. The Mills ratios are then used in the second stage of the Heckman method as independent variables to calculate the potential wages that each of the workers would earn in each of the markets. Other socioeconomic characteristics of the households are also included in the regression such as the age of the household head and its square, a dummy equal to one if the household head is a male, education status and its square, marital status, and a dummy variable for department.[3] The results of the linear regressions for estimating the potential wages are shown in table A.3.

The potential wages for each of the workers in each of the markets are calculated as the fitted values of wages in the OLS regressions. Changes in wages are applied to each of these potential wages to determine whether or not the worker has an incentive to migrate to other labor markets. Following Cogneau and Robilliard (2006) and Savard (2003), the location of each of the labor markets for worker i is given by the following scheme:

1. The worker i chooses the rural sector if $w_i^R > w_i^E$.
2. The worker i chooses being unemployed if $w_i^0 > w_i^R$, $w_i^0 > w_i^I$, and $w_i^0 > w_i^F - cost_f$.
3. The worker i chooses the informal sector if $w_i^I > w_i^R$, $w_i^I > w_i^0$, and $w_i^I > w_i^F - cost_f$.
4. The worker i chooses the formal sector if $w_i^F - cost_f > w_i^R$, $w_i^F - cost_f > w_i^0$, and $w_i^F - cost_f > w_i^I$,

where w_i^R is the rural potential wage of worker i; w_i^0 is the urban reservation wage of worker i; w_i^I is the informal potential wage of worker i; and $w_i^F - cost_f$ is the formal potential wage of worker i minus a cost of entry to the formal market, which is also estimated econometrically. The definition of the expected wage (w_i^E) which enters into the migration decision of rural workers, follows Harris and Todaro (1970): it is equal to the product between urban wages (both informal and formal wages) and the probability of getting a job in the urban sector (in the informal and formal markets). Unemployment in both urban and rural areas is considered in the migration decision.[4]

Once each of the workers has chosen in which labor market to work, the labor supply is calculated as the sum of the workers in each market, taking into consideration the expansion factors of the survey. The labor supply is then used as an input in the CGE model to calculate a second round of macro changes. The mechanism by which the two models are interconnected is described in section A.5.

[3] Colombia is divided in 32 departments. The capital city, Bogota, has its own geographical division named district capital.
[4] Following official statistics and estimates done by the author, an unemployment rate of 10% is considered in both areas.

A.3 The Almost Ideal Demand System (AIDS)

The second microeconomic model used to feed the CGE model is the AIDS. The AIDS allows to model households behavior of the CGE model taking into consideration the microeconomic theory. The AIDS was developed by Deaton and Muellbauer (1980b) as an alternative approach to the linear and the translog models in the literature. The main difference with the linear models is that the AIDS does not assume straight Engel curves for different households considering the different income levels between groups. Additionally, it is more flexible than the other models, allowing for the estimation of many free parameters as there are independent economic parameters such as the cross-price and income elasticities of demand.

Additionally, two modifications are considered when estimating the AIDS. The first one is the inclusion of an equivalence scale of sociodemographic characteristics that affect the estimation of the expenditure function following the methodology proposed by Ray (1983). The second one is the estimation of the shares using censored data following the two-stage estimation proposed by Shonkwiler and Yen (1999). A similar approach, used by Atuesta and Paredes (2011), calculates the AIDS model for Colombia with censored data to estimate a spatial cost of living index for the country.[5]

According to the AIDS, the preferences of a rational consumer are represented by the following expenditure function:

$$c(p,u) = (1-u)\log(a(p)) + u\log(b(p)), \tag{A.3}$$

where

$$\log(a(p)) = \alpha_0 + \sum_{i=m}^{m} \alpha_i \log p_i + \frac{1}{2}\sum_{i=1}^{m}\sum_{j=1}^{m} \gamma_{ij} \log p_i \log p_j, \tag{A.4}$$

and

$$\log(b(p)) = \log(a(p)) + \beta_0 \prod_i p_i^{\beta_i}. \tag{A.5}$$

Both, namely $\log(b(a))$ and $\log(b(p))$, are homogeneous of degree one in prices satisfying the theoretical restrictions of the expenditure function. Because the consumption shares are the derivatives of the expenditure function with respect to prices (Shepard's lemma), the estimable shares are defined as:

$$s_i = \alpha_i + \sum_{j=1}^{m} \gamma_{ij} \log p_j + \beta_i(\log w - (\alpha_0 + \log a)), \tag{A.6}$$

where α, β and γ are parameters of the model; s_i is the budget share of good i; p_i is the price of good i; and w is total expenditure.

[5] In that paper, only the food consumption is considered, and the estimation is done only for urban areas.

The first modification of this estimable share is proposed by Ray (1983) who included a general equivalence scale to control for demographic characteristics of each of the households. This equivalence scale enters into the equation twice: the first way is through a basic element which is constant across price distributions and utility $\overline{m}_0$, while the second one is through an element that varies across utility φ. the function φ is defined such that the theoretical restrictions of the expenditure function remain unaffected. For the AIDS, the best way of defining φ is the following:

$$\varphi(z,p,u) = \exp\left(u\prod_j p_j^{\beta_j}\left\{\prod_j p_j^{\theta_{1j}z_1+\theta_{2j}z_2}-1\right\}\right). \tag{A.7}$$

The second modification uses censored data in the estimation of the shares, needed to correct for the bias generated by the households that reported zero consumption. Perales and Chavas (2000) analyzes the causes of zero consumption in the case of Colombian households. After studying the distribution of the zero expenditures by income class and within income groups, the authors conclude that the zero shares are explained because some goods are too expensive for some of the households to consume. The bias produced by these corner solutions is reduced by including censored data in the estimation following the methodologies of Heien and Wessels (1990) (H-W hereafter) or Shonkwiler and Yen (1999) (S-Y hereafter).

In this paper the two-stage method proposed by S-Y is used.[6] The first step uses a binary variable equal to one if the household consumed the good and zero otherwise, and regresses it as a function of demographic and socioeconomic characteristics. Probit models are estimated for each of the consumption goods and the cumulative (Φ) and the density (ϕ) probability functions are estimated. In the second step, the estimation of the shares includes the cumulative probability function as a scalar multiplying the non-linear part of the equation, while the density function enters as an extra linear variable in the estimation.

The modified estimable shares, for the nine different consumption categories, with the demographic equivalent scale and censored data has the following functional form:

$$\begin{aligned} s_i = \quad & \Phi[\alpha_i + \textstyle\sum_{j=1}^{m}\gamma_{ij}\log p_j + (\beta_i + \theta i1 z_1 + \theta_{i2}z_2 + \theta i3 z_3)(\log w \\ & -(9+\log(1+\rho_1 z_1+\rho_2 z_2+\rho_3 z_3)+\log a))] + \delta\phi, \end{aligned} \tag{A.8}$$

where $\log a = \alpha_0 + \sum_{i=m}^{m}\alpha_i \log p_i + \frac{1}{2}\sum_{i=1}^{m}\sum_{j=1}^{m}\gamma_{ij}\log p_i \log p_j$.

α, β, γ, θ and ρ are parameters of the model; s_i is the budget share of good i; p_i is the price of good i; and w is total expenditure. z_1, z_2 and z_3 are number of persons in the household, education of the household head, and location (rural or urban) of the household respectively; and δ is an extra parameter of the model

[6] S-Y use Monte Carlo simulations to compare the bias reduction of their method with the bias reduction using the methodology proposed by H-W. The results suggest that H-W estimator is inconsistent and performs poorly.

with no restrictions. In order to maintain the additivity restriction of the shares, the system estimates $n-1$ equations, where n is the number of shares, and the last share is recovered as a residual of the $n-1$ shares.

The β parameters provide information about the characteristics of the goods with respect to income level. If $\beta_i > 0$, an increase in the expenditure would increase the budget share of i, then, the good i is a luxury. On the contrary, if $\beta_i < 0$, the good i is a necessity. The parameters γ measure the changes in the budget shares following a change in the relative prices.

The AIDS model satisfies restrictions of adding-up, homogeneity and symmetry: it adds up to total expenditure (the sum of the budget shares is equal to the total expenditure), it is homogeneous of degree zero in prices and total expenditure, and the total expenditure satisfies the Slutsky symmetry.[7] These theoretical restrictions above are imposed through the linearity of the parameters in the following way:

$$\sum_{i=1}^{n} \alpha_i = 1, \qquad \sum_{i=1}^{n} \gamma_{ij} = 0, \qquad \sum_{i=1}^{n} \beta_i = 0, \qquad \sum_{j=1}^{3} \theta_{ij} = 0, \tag{A.9}$$

$$\sum_{j} \gamma_{ij} = 0, \tag{A.10}$$

$$\gamma_{ij} = \gamma_{ji}. \tag{A.11}$$

As in the labor participation model, the GEIH of 2007 for Colombia is used. Unitary prices are only reported for the "food" category. However, the DANE provides price indexes for 79 goods and services for low-, middle- and high-income households. Once the goods and services of the Survey are aggregated into these 79 categories, prices are assigned according to the level of income of the households (low, middle and high). In order to have an AIDS model compatible with the CGE model, the nine categories included in the SAM should be the same as the ones used for the estimation of the AIDS. Following Urzua (2010), the weighting factors for each of the nine goods are calculated for each household:

$$a_{jh} = \frac{w_{jh}}{W_{ih}}, \tag{A.12}$$

where w_{jh} is the expenditure of household h in the individual good j that belongs to group i (where j = 1...1,055,945), and W_{ih} is the total expenditure of household h in group i (where j = 1...9). Using these weights and the unit prices assigned for each of the individual goods, the composite price of group i is calculated as:

$$P_i = p_1^{a_1} p_2^{a_2} \dots p_n^{a_n}. \tag{A.13}$$

[7] The Slutsky symmetry means that $\frac{\partial h_i(p,u)}{\partial p_j} = \frac{\partial^2 e(p,u)}{\partial p_j \partial p_i} = \frac{\partial h_j(p,u)}{\partial p_i}$; where $h_i(.)$ and $h_j(.)$ are the Hicksian demands of goods i and j respectively; p are prices and u is the level of utility.

This is the price of group i used in the estimation of the AIDS. The composite expenditure of group i is the sum of the expenditures of each of the goods j which belong to group i. The budget shares are easily estimated by dividing the expenditure of each of the groups over the total expenditure of the household. The AIDS is estimated using a non-linear seemingly unrelated regression (nlsur) where the shares are the dependent variables, and the prices, total expenditures, socio-demographic characteristics and the density functions (ϕ) are the independent variables.

The results of the Probit models estimated in the first stage are shown in table A.4. Households with lower socioeconomic status and a greater number of household members have greater probability of consuming food, clothing, housing, health, tobacco and alcohol and other services; while households with a greater socioeconomic status and lower number of household members have a greater probability of consuming education, transportation and cultural services. The consumption share of food increases when the household head is a female, while the consumption share of the other eight groups increase when the household head is a male. Older household heads have a lower probability of consuming clothing, tobacco and alcohol, and transportation services. The level of education increases the consumption shares of all the consumption groups, and urban households are more likely to have greater consumption shares of housing, education and transportation than rural households.

The coefficients of the estimable shares are shown in table A.5. Most of the coefficients are significant at the 95% level, excepting some of the θ parameters of the equivalent component for demographics. The parameters of the AIDS are used to estimate budget shares for all households, and the median share of each income group are then used as parameters for the CGE model. The AIDS model is also used for estimating the welfare measures of each income group, once the changes in income and prices have been calculated in the CGE model.

Two measures of welfare are used in the analysis. The first one is the compensated variation (CV) that measures how much money the consumer has to receive in order to offset the losses of the price increase. The second one is the equivalent variation (EV) that measures how much money the consumer has to give away in order to have a loss equal to the price increase. Both measures answer the same problem: how much extra income is needed in order to offset the price changes. Then, *negative* EV and CV mean that the consumer receives a *gain* in economic welfare, and positive measures mean a loss in economic welfare. The CV and EV are defined as:

$$CV(p^0, p^1, w) = e(p^0, u^0) - e(p^1, u^0) = w - e(p^1, u^0), \tag{A.14}$$

$$EV(p^0, p^1, w) = e(p^0, u^1) - e(p^1, u^1) = e(p^0, u^1) - w, \tag{A.15}$$

where $e(p^i, u^j)$ is the expenditure function estimated with prices i and utility j. The expenditure function is calculated using two different price indexes: $log(a)$ which is defined before in equation A.8, and $b(p)$ which is defined as:

$$b(p) = \prod_{i=1}^{n} pi^{\beta_i}. \tag{A.16}$$

A.4 The CGE model

A.4.1 Construction of the Social Accounting Matrix (SAM)

The main source of data for the CGE model comes from the SAM. The SAM is built following Corredor and Pardo (2008) using Colombian data from 2006. The National Department of Statistics, DANE, provides the tables required for the construction of an aggregated SAM: the utilization matrix (UM), the supply matrix (SM) and the general economic equilibrium matrix (GEE). The UM shows the final and intermediate demand for each of the products in the economy. The final demand is disaggregated into domestic consumption and exports. The SM shows the components of the total supply for each product at producers' prices. The final supply consists of imports, domestic production, taxes, import taxes, and commercial and transportation margins. Finally, the GEE shows the economic activities of the institutions. The DANE disaggregates the demand into five institutions: households, financial firms, non-financial firms, government and non-profit organizations.

The production side is disaggregated into ten legal sectors and one illegal sector: illegal drugs, food, housing, clothing, health, education, culture, transportation (infrastructure), addictions (alcohol and tobacco), other services and security. All products, excepting the security and health services, are both imported and exported. The main exports come from the transportation and the food sectors (46% and 16% respectively). The exports of illegal drugs represent only the 3.37% of the total exports. The highest level of imports is observed in the housing sector followed by the transportation sector (44.35% and 17.93% of the total imports respectively).

Additionally, the DANE provides a "satellite" account for the illegal drug activities which is used to model the illegal drug market. According to the definition provided by the System of National Accounts of 1993 (SNA93), "satellite accounts are linked with the central framework of national accounts and through them to the main body of the integrated economic statistics. (...) Because they preserve close connections with the central accounts, they facilitate analyses of specific fields in the context of macroeconomic accounts

and analyses" (SNA, 1993).

The Quality of Life Survey for 2003 and the GEIH of 2007, both conducted by the DANE, are used to disaggregate the factors of production and the demand side of the SAM. Corredor and Pardo (2008) also provide tables explaining how this disaggregation is accomplished. Households are divided into income deciles and labor is disaggregated into three different labor forces, rural labor, urban informal labor, and urban formal labor, and unemployment. However, an additional household disaggregation by location is needed in order to analyze the effects of legalization in rural and urban areas. To accomplish this task, the 2005 Census, also conducted by the DANE, is used to divide households into rural and urban areas. Finally, a disaggregation of households by location and by deciles is obtained yielding in total 20 representative households (ten rural and ten urban).

After the disaggregation, the original SAM is rebalanced using the RAS method first developed by Stone and Brown (1962). Households are the owners of the factors of production and receive money from them. However, the illegal activity only uses a factor of production called the *illegal factor* which is not paid to the households but to the rest of the world. This account is called *income leakage* and basically represents the opportunity cost of the prohibition (money the households are not receiving because of the illegality of the drugs). The SAM is built in a way that the urban households only provide urban labor and the rural households only provide rural labor.

A.4.2 The benchmark economy

The CGE model is drawn following one of the standard frameworks developed by the IFPRI (Lofgren et al., 2002) with additional modifications in order to suit the Colombian economic situation. Colombia is treated as a small-open economy where the international prices are given and are only affected by an exchange rate that is assumed to be flexible (fixed foreign savings). Producers and consumers maximize their profits and utility respectively. Producers use Cobb-Douglas production functions that are estimated endogenously by the model. Consumption is estimated endogenously but using the budget shares previously estimated in the AIDS as exogenous parameters.

Constant elasticity of substitution functional forms are used to measure the imperfect substitution between imports and domestic output sold domestically (the Armington function), and between exports and domestic output sold domestically (also known as the output transformation function). The elasticity of substitution between imports and domestic goods, and the elasticity of substitution between exports and domestic sales are set exogenously.

Capital is fully employed and not mobile, following the assumption that specific capital is needed for

each of the economic activities. The "illegal factor" is also fully employed and immobile because it cannot be used for any other economic activity. In both cases, the wages and the factor demands are fixed. Labor supplies in rural areas and in the three different urban labor markets are set exogenously and are estimated using the labor participation model. The households receive money from the factors of production, transfers from the government and transfers from the rest of the world. The government receives income from taxes, tariffs, capital and transfers from the rest of the world; and spends it on consumption (of manufacturing, services, security and health), transfers to households, and savings (or investment depending on the sign of the account). The government is the only institution that spends money on security because security is considered a public good provided by the state.

The model includes three closures. The first one is that investment is saving-driven, meaning that investment is defined in terms of savings in order to satisfy the savings-investment quality, $SAV - INV = 0$. The second one is the closure of the factors of production: capital and illegal drugs are fully employed and not mobile, and the labor supplies are fully mobile in order to allow migration between different labor markets. Finally, the foreign savings are fixed and the model uses a flexible exchange rate to adjust prices and clear the current account.

A.5 Linkages between the microeconomic models and the CGE

When analyzing the impact of macroeconomic shocks, macroeconomic models should be combined with micro models in order to simulate the effect of the shock in many different dimensions, and consequently, to the specific individual households. This section explains the interaction between the two microeconomic models described above and the CGE model. The shock is imposed to the CGE model affecting all the agents in the economy. Then, changes predicted by the CGE model are then applied to the microeconomic models to simulate the microeconomic behavior of each of the household groups.

When all households are affected by the same policy, it is necessary to analyze not only the micro counterfactual (impacts within the same group), but also the macro counterfactuals (impacts between different groups) (Bourguignon et al., 2008). The literature describes several methods to introduce micro analysis in macroeconomic models. The simplest one is to introduce heterogeneous representative households in the CGE models. Instead of assuming that all households behave in the same way (one representative household at the national level), the assumption here is that all households *within* a specific group behave in the same way. This approach is useful when the policy implemented does not affect the intra-distribution of income within each of the household groups. Extensions of this approach have tried to increase the level of house-

hold's behavior heterogeneity by including as many representative households in the CGE as the number of households in the economy (see Lofgren et al., 2003; and Dervis et al., 1982).

The macro models with representative households have been criticized because it is not possible to model microeconomic behavior within groups with just one observation (one representative household per group). Then, all households must have the same budget shares because the demand is not estimated econometrically (Bourguignon et al., 2008). To introduce household level data in macro models, three approaches have been suggested by the literature: the top-down accounting modeling, the top-down simulation modeling, and the feedback loops from top to bottom. The top-down accounting modeling uses results from the CGE model as a shock to the household level micro model to estimate policy implications at the microeconomic level. The households in this case do not change the behavior of consumption or labor participation with the new information. The changes from the CGE model only affect the outcome of the micro model without considering behavioral effects. The criticism of this approach is that it is only consistent when the markets are competitive or when the changes at the macro level only affect in a marginal way the budget of individuals (Bourguignon et al., 2008).

The top-down simulation modeling considers the behavioral responses of individual from a macro shock. When changes in prices, income and wages are calculated at the macro level, these changes enter into the decision-making of the households changing their consumption and labor participation patterns. With non-competitive markets or rationed markets, considering these second-round effects is needed in order to have a simulation consistent to household economic behavior.

Finally, Savard (2003) suggests a third method that includes feedback loops from top to bottom until convergence is achieved. He explains that, in order to have coherence between the CGE model and the household models, it is necessary to obtain a converging solution between the two models. When these results are compared with those that use only a top-down approach, Bourguignon and Savard (2008) show that a bias is generated by ignoring the feedback effects from the micro to the macro models, particularly when analyzing labor markets.

In this specific case, feedback loops from top to bottom are considered between the CGE and the labor participation models using behavioral responses at the micro level. When the shock is implemented in the CGE model, changes in prices, wages and household income are calculated. Workers receive information about the new wages and migrate according to their individual preferences, following the labor participation scheme proposed in section A.2. Once workers move from one labor market to the other, the total number of workers in each labor market is re-estimated in order to calculate the new labor supplies. These new labor supplies are then compared to the initial supply levels and the percentage changes are used to "feed" the

CGE model.

The CGE model receives this new information about the labor supplies as a shock to change again prices, income and wages. A new level of wages is calculated and used again in the labor participation model to calculate changes in labor supplies. These iterations between the CGE model and the labor participation model continue until the models achieve convergence. According to Savard (2003), by including these iterations between the micro and the macro model, the bias of using different data sources in each of the model is minimized and the simulations produce more accurate results.

The iteration between the CGE model and the AIDS is simpler. The AIDS is used to estimate the consumption shares of each of the household groups, and these shares are included as parameters in the CGE model. The shock is imposed in the CGE model and the iteration between the CGE model and the labor participation model begins. Once these two models find convergence, the changes in prices and income of the CGE model are used in the AIDS to calculate the welfare measures for each of the household groups. These measures are calculated based on a median representative household, but they can also be calculated for different percentiles of the intra-group income distribution.

Both, the labor participation model and the AIDS use the feedback loops with the CGE model. However, only the labor participation model assumes microsimulations in which the individual behavior is fed from the macro shock, and at the same time, it estimates the changes in labor supply that are going to be used for the reestimation of the macro shock itself. The relationship between the AIDS model and the CGE model is straightforward: the shares are used *ex ante* to the macro shock, and the AIDS parameters are used *ex post* for the estimation of welfare measures once the utility and the expenditure functions, evaluated at the new prices and income, have been recovered.

A.6 Conclusions

In this paper, a methodology that links macro models to microeconomic models is explained. This methodology is useful for simulating the effects at the household level of imposing a macroeconomic shock to the economy. Because the shock would affect all the agents of the economy, a general equilibrium framework is needed. Once the changes at the macro level have been calculated, the microeconomic models are used to estimate the impact of the shock at the household level. In this specific example, two microeconomic models are used in order to understand migration decisions following labor participation of individuals, and consumption patterns.

Assuming imperfect labor markets with unemployment, using only top-down accounting models does not

provide a result consistent with microeconomic behavior. For this reason, it is necessary to link the labor participation model and the CGE model using simulation techniques and feedback loops from top to bottom. The simulation techniques take into consideration the behavioral responses of households to the shock. In other words, the shock would change not only the outcome of the household decision, but the household taking-decision process itself. In the case of the AIDS model, this simulation is not needed because the changes only affect marginally the household budgets. Then, once the budget shares are estimated in a first round and included in the CGE model, the macro shocks are calculated and the results are used for the calculation of welfare measures.

By using data for Colombia, and an application that simulates the effect of legalization of drugs in the Colombian economy, this methodology is used in Chapter 4 to calculate the changes in economic welfare of households. The CGE and the labor participation models converge after three iterations, and the AIDS is then used for calculating welfare measures. After estimating six scenarios with different assumptions about the prices, future of the armed conflict predictions, and government reinvestment, the author concludes that the economic welfare gains of legalizing drugs are too small if the social cost of war and drug addiction is not considered.

Table A.1: Summary of statistics of demographic characteristics of households by labor sector. Standard deviations in parentheses.

	Labor sectors			
	Rural	Unemployed	Informal	Formal
Ln wage	14.78	0	14.08	14.95
	(1.64)	(0)	(3.23)	(3.12)
Male (%)	0.71	0.45	0.68	0.75
	(0.45)	(0.50)	(0.47)	(0.44)
Age HH head	48.13	57.63	45.73	41.21
	(15.70)	(17.12)	(12.62)	(41.21)
Education	2.65	3.25	3.47	4.52
1-6 (low-max)	(1.81)	(1.82)	(1.72)	(1.54)
Number of kids	3.76	3.59	3.75	3.47
(¡3 years old)	(1.96)	(2.04)	(1.86)	(1.61)
Husband (%)	0.64	0.43	0.63	0.69
or wife	(0.48)	(0.49)	(0.48)	(0.46)
Working persons	1.40	0.91	1.77	1.67
in HH	(0.94)	(1.04)	(0.93)	(0.82)

Table A.2: Bivariate Probit models for the different labor markets.

First Probit	**Prob. Rural**		**Prob. Urban**		**Prob. Urban**		**Prob. Urban**	
	coefficient	**S.E.**	**coefficient**	**S.E.**	**coefficient**	**S.E.**	**coefficient**	**S.E.**
socioec. status	-0.31	0.0004	0.28	0.0004	0.30	0.0004	0.30	0.0004
No. persons in HH	0.01	0.0003	-0.01	0.0003	-0.02	0.0003	-0.02	0.0003
No. occupied	-0.04	0.0005	0.08	0.0005	0.10	0.0005	0.10	0.0005
male	0.19	0.0009	-0.20	0.0009	-0.16	0.0009	-0.17	0.0009
education	-0.16	0.0003	0.16	0.0003	0.16	0.0003	0.17	0.0003
marital status	-0.10	0.0016	0.03	0.0016	0.09	0.0016	0.07	0.0016
other income	-0.36	0.0011	0.39	0.0011	0.38	0.0011	0.39	0.0012
age HH head	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000
constant	1.15	0.0025	-1.02	0.0026	-1.09	0.0025	-1.02	0.0025
Second Probit	**Prob. Employed**		**Prob. Unemployed**		**Prob. Informal**		**Prob. Formal**	
	coefficient	**S.E.**	**coefficient**	**S.E.**	**coefficient**	**S.E.**	**coefficient**	**S.E.**
socioec. status	-0.26	0.0004	0.17	0.0005	0.06	0.0005	0.18	0.0005
No. persons in HH	-0.02	0.0003	0.09	0.0003	-0.06	0.0003	-0.05	0.0003
No. occupied	0.10	0.0005	-0.36	0.0006	0.25	0.0005	0.23	0.0005
male	0.60	0.0010	-0.58	0.0010	0.10	0.0010	0.26	0.0010
education	-0.13	0.0003	0.08	0.0003	0.02	0.0003	0.18	0.0003
marital status	-0.06	0.0017	0.10	0.0017	0.00	0.0019	0.12	0.0019
other income	-0.54	0.0013	0.57	0.0011	-0.11	0.0014	-0.12	0.0014
age HH head	-0.01	0.0000	0.02	0.0000	0.00	0.0000	-0.02	0.0000
constant	0.71	0.0026	-2.41	0.0030	-1.22	0.0029	-1.27	0.0029
N	10974961.00							
rho	0.9956	0.0000	0.9950	0.0001	0.9731	0.00035	0.9867	0.0004
Log likelihood	-8736257.00		-9171928.80		-9860755.70		-9838944.10	

All the estimations are weighted by the expansion factors to be representative of the population.

Table A.3: OLS estimates for the prediction of wages for each worker in each of the labor markets.

	log (rural wage)		**log (reservation wage)**		**log Informal wage)**		**log (formal wage)**	
	coefficient	**S.E.**	**coefficient**	**S.E.**	**coefficient**	**S.E.**	**coefficient**	**S.E.**
age HH head	0.0461	0.0002	0.0183	0.0005	0.0114	0.0010	0.1059	0.0012
age^2	-0.0004	0.0000	-0.0002	0.0000	-0.0002	0.0000	-0.0012	0.0000
male	0.3606	0.0015	0.2433	0.0034	0.3684	0.0047	0.1915	0.0038
education	-0.0756	0.0012	-0.3125	0.0036	-0.2016	0.0066	-0.3915	0.0049
education^2	0.0396	0.0002	0.0266	0.0005	0.0347	0.0008	0.0452	0.0006
marital status	0.6854	0.0026	0.8367	0.0029	1.0370	0.0093	0.1973	0.0065
Mills ratio	0.3929	0.0061	-1.4831	0.0084	-1.0332	0.0140	-1.6799	0.0122
constant	12.5161	0.0062	15.6193	0.0180	15.1608	0.0319	15.1714	0.0281
R2	0.1534		0.1269		0.1057		0.0879	
N	4,833,540		2,127,235		1,652,804		2,361,382	

Robust standard errors. Regressions are weighted by the expansion factors. All regressions include dummy variables for department.

Table A.4: Probit estimation for household consumption: first stage of S-Y estimator.

	group 1	group 2	group 3	group 4	group 5	group 6	group 7	group 8	group 9
socioec. Status	-0.1614	-0.0863	-0.0040	-0.0012	0.0130	0.0733	0.0069	-0.0374	-0.1408
No. persons	0.0245	0.0282	0.0217	0.0033	0.3149	-0.0048	-0.0176	-0.0056	0.0363
No. persons working	-0.0055	-0.0079	0.1200	0.0556	-0.1266	0.1619	0.2458	0.1615	-0.0282
male	-0.0459	0.1872	0.1067	-0.0313	0.0961	0.2163	0.0669	0.3042	0.1597
skill	-0.0436	0.0381	0.0582	0.0324	-0.0457	0.0903	0.0885	0.0173	-0.0114
age partner	-0.0021	-0.0019	-0.0064	0.0016	-0.0156	-0.0050	0.0020	0.0043	-0.0018
age HH head	0.0056	0.0094	-0.0058	0.0015	0.0032	0.0009	-0.0016	-0.0045	0.0042
wage	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
education	0.0244	0.0727	0.0822	0.0565	0.1020	0.0952	0.1084	0.0492	0.0732
rural vs. urban	-0.2122	0.0971	-0.0243	-0.0620	0.0923	-0.0318	0.1109	-0.0434	0.1175
constant	1.3947	1.1752	0.1795	-0.1000	-0.7316	-1.1083	-0.3018	-1.2466	1.4080
Pseudo R2	0.0263	0.0144	0.0334	0.0089	0.1097	0.0468	0.0593	0.0307	0.0154

All the estimations are weighted by the expansion factors to be representative of the population.

All coefficients are significant at 0.005 level.

The groups are the following: 1: food; 2: housing; 3: clothing; 4: health;

5: education; 6:culture; 7:transportation; 8: tobacco and alcohol; 9: other services.

Table A.5: Coefficients of the AIDS model with censored data and equivalent component.

	Coeff.		Coeff.		Coeff.		Coeff.		Coeff.
α_1	0.287***	γ_{11}	-0.233***	θ_{11}	0.014***	δ_1	-0.217***	ρ_1	-0.841***
α_2	0.137***	γ_{12}	0.053***	θ_{21}	0.013***	δ_2	0.497***	ρ_2	0.896***
α_3	-0.063***	γ_{13}	0.134***	θ_{31}	-0.009***	δ_3	0.142***	ρ_3	-0.071***
α_4	0.018***	γ_{14}	0.026***	θ_{41}	-0.000	δ_4	0.052***		
α_5	0.097***	γ_{15}	0.085***	θ_{51}	0.006***	δ_5	0.048***		
α_6	0.058***	γ_{16}	0.035***	θ_{61}	-0.001***	δ_6	0.059***		
α_7	0.285***	γ_{17}	0.067***	θ_{71}	-0.036***	δ_7	0.184***		
α_8	-0.085***	γ_{18}	0.072***	θ_{81}	0.018***	δ_8	0.183***		
β_1	-0.080***	γ_{22}	-0.162***	θ_{12}	-0.002***				
β_2	0.026***	γ_{23}	0.048***	θ_{22}	0.000***				
β_3	0.023***	γ_{24}	0.002***	θ_{32}	0.000**				
β_4	0.001***	γ_{25}	0.017***	θ_{42}	0.000				
β_5	0.026***	γ_{26}	-0.026***	θ_{52}	0.000***				
β_6	-0.003***	γ_{27}	0.098***	θ_{62}	0.001***				
β_7	0.058***	γ_{28}	-0.005***	θ_{72}	-0.001***				
β_8	-0.072***	γ_{33}	-0.227***	θ_{82}	0.005***				
		γ_{34}	-0.007***	θ_{13}	0.005***				
		γ_{35}	0.027***	θ_{23}	-0.001***				
		γ_{36}	-0.024***	θ_{33}	-0.006***				
		γ_{37}	0.079***	θ_{43}	-0.001***				
		γ_{38}	0.074***	θ_{53}	-0.002***				
		γ_{44}	-0.061***	θ_{63}	0.003***				
		γ_{45}	0.022***	θ_{73}	-0.001***				
		γ_{46}	-0.005***	θ_{83}	0.003***				
		γ_{47}	0.010***						
		γ_{48}	0.004***						
		γ_{55}	-0.030***						
		γ_{56}	-0.075***						
		γ_{57}	0.033***						
		γ_{58}	0.015***						
		γ_{66}	0.096***						
		γ_{67}	0.053***						
		γ_{68}	-0.027***						
		γ_{77}	-0.358***						
		γ_{78}	0.163***						
		γ_{88}	-0.235***						

*, ** and *** represent the level of significance to 10%, 5% and 1%, respectively.

Appendix B

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